THE UNIVERSITY OF ALBERTA

CARDIORESPIRATORY ADAPTATIONS TO TRAINING AT SPECIFIED INTENSITIES IN CHILDREN

by

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A THESIS

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ABSTRACT

The purpose of this study was to determine the relative effects of three intensities of training upon the cardiorespiratory fitness of children when the groups were equated on the initial fitness level, as well as the duration and frequency of the training sessions.

Thirty-six subjects (mean age 12.5 years) were tested on a bicycle ergometer prior to and following a six week training program. The subjects were ranked according to $M\dot{V}O_2$ relative to body weight and then blocked into three fitness levels. The subjects from each fitness level were then randomly assigned to one of four treatment groups. The first group (T1) trained at a heart rate of 170-180 beats/minute; the second group (T2) trained at a heart rate of 150-160 beats/minute; the third group (T3) trained at a heart rate of 130-140 beats/minute and the fourth group (T4) acted as a control. The training was conducted on a bicycle ergometer three times a week, twelve minutes per session. The heart rate was monitored once a week during the twelve minutes to permit an adjustment of the work load required to elicit the pre-determined heart rates.

Following training, significant decreases in heart rate occurred for the three training groups over the control

group at submaximal work load. There was no significant difference, however, between the three training groups. Blood lactate concentration decreased in the T1 group at submaximal work load. After training, $M\dot{V}O_2$, maximal blood lactate concentration and maximal oxygen pulse increased significantly in only the T1 group. Significant increases in maximal work loads were found with training for the three training groups over the control group. There was no significant difference, however, between the three training groups.

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CHAPTER I

INTRODUCTION

Generally, physical fitness denotes a quantitative and unspecified evaluation of the individual's physical state.

> "Fitness consists in the ability of the organism to maintain the various internal equilibria as closely as possible to the resting state during strenuous exertion and to restore promptly after exercise any equilibriums which have been disturbed (Astrand (9))."

Specifically, the ability to perform prolonged hard physical work is related to the capacity of the cardiovascular and respiratory systems to take-up, transport, and give off oxygen to active tissues. The physical fitness of the individual is determined by his natural endowment and by the way this has been adapted to physical work, i.e. the training condition. In the last decade, the attention of many exercise physiologists has been focused on the question of possible minimal or optimal cardiorespiratory training stimuli, their arrangements, application and possible interactions. The training factors most frequently mentioned

are exercise intensity, duration, frequency and initial fitness level.

Some studies (38, 93, 103, 105, 120) dealing with exercise intensity have tended to indicate that the effects of training are directly related to the intensity of exercise. Wenger (120) equated groups in total work performed during training and initial fitness level and found a significantly greater improvement of maximum oxygen consumption in the highest intensity training group. Some other exercise frequency and duration studies (16, 63, 88, 101, 102, 123) have suggested that fitness improvements are noted most often in the longest training periods. However, an inspection of data reveals that in certain important training criteria, such as the maximum oxygen uptake, the exercise heart rate and the oxygen pulse, the changes are most pronounced in the moderate duration and frequency groups (63, 102, 123).

Karvonen's interest (67, 68), directed toward discovering the minimum heart rate necessary to elicit cardiovascular improvement, inspired the current attention in heart rate as a key factor in training. These researchers Karvonen (67, 68), Roskam (93), Sharkey and Hollman (103) contended that to improve the exercise tolerance of the cardiorespiratory system the heart rate during the exercise

bout must be increased above resting levels by at least 60% of the difference between the resting and maximal rates, or to about 150 beats per minute. However, these studies were carried out using adult subjects.

STATEMENT OF THE PROBLEM

This study was designed to determine the relative effect of three different intensities of training upon improving cardiorespiratory functions of children. The specific functions under study being:

1. Maximum oxygen consumption
2. Maximum heart rate
3. Maximum exercise pulmonary ventilation
4. Maximum blood lactate concentration
5. Heart rate, oxygen consumption, pulmonary ventilation and blood lactate concentration at a given submaximal work load.
6. Oxygen pulse, ventilatory equivalent and respiratory quotient at submaximal and maximal work loads.

JUSTIFICATION OF THE STUDY

Most studies concerning training effects on physical condition have been carried out on adults (4, 24, 33, 42, 53, 54, 63, 78, 88, 90, 97, 105, 122). The improvement of the physical fitness of youths should be one of the principal objectives in physical education. A great deal of work has

been done to investigate the value of sports participation or such intensive training systems for regular physical education programs with children, but these lacked a control over the intensity of work done during the experiment and also over the initial fitness level (30, 32, 41, 64, 92). The present study was designed to determine how much effort was required to elicit a desirable training response in children. Information gained from a study of the relationship of training intensity to the improvement of the physical fitness of youths has practical consequences for those engaged in physical education, athletics, physical rehabilitation and sport medicine.

In trying to discover the effects of training intensity upon cardiorespiratory fitness, it was necessary to equate groups on the initial fitness level, as well as frequency and duration of the training sessions. The training intensity was controlled by the heart rate as follows: group (T1) trained at 170-180 beats per minute, group (T2) at 150-160 beats per minute and group (T3) at 130-140 beats per minute; group (T4) acted as a control. These training heart rates corresponded to approximately 75-85%, 60-70% and 45-55% of the difference between the resting and maximal rates (see definition of training heart rate in percentage).

If the low intensity (i.e. 130-140 beats/min.), or the medium intensity (i.e. 150-160 beats/min.) groups were to show as much improvement as the high intensity (i.e. 170-180 beats/min.) group, this would indicate that there is no need to incorporate severe training exercises in school programs of physical education. A less severe training (ranging from 130 to 160 beats/min) might be as beneficial physiologically and probably more enjoyable for this age group of children. However if the high or medium intensity groups improved more than the low intensity group, some light could be shed on the question of the training threshold to improve the physical working capacity of this age group of children.

DELIMITATIONS OF THE STUDY

Thirty-six (36) students of the College St-Jean, aged 11-13 years, participated voluntarily in this study.

LIMITATIONS OF THE STUDY

The subjects were asked to engage in the same sport activities as they had before the study; it was impossible to control the activities outside of the training session.

DEFINITIONS AND ABBREVIATIONS OF TERMS

Aerobic metabolism: Sources of energy from atmospheric oxygen provided by the respiratory and circulatory transport systems.

Aerobic power: Aerobic power and maximal oxygen uptake are considered to be synonomous.

Aerobic work: A given amount of work for which the oxygen supply is sufficient and hence anaerobic metabolism is not required to augment the aerobic energy processes (120).

Anaerobic metabolism: Sources of energy provided by: 1) the transformation of pyruvic acid to lactic acid in the glycogen degradation cycle; 2) the oxygen stored in oxyhemoglobin and oxymyoglobin forms; 3) the ATP and phosphocreatin. The end product is lactic acid.

Anaerobic work: The accomplishment of a given amount of work for which the oxygen supply is not sufficient and hence anaerobic sources of energy must be utilized.

Anova: Analysis of variance.

Blood lactate: The lactic acid which is in the blood in the combined state with the blood buffers. Lactic acid is the end product of anaerobic metabolism of carbohydrate and is used as a measure of the extent to which the anaerobic energy supply mechanism has been engaged (120). Expressed in milligrams per hundred millilitres of blood (mg%).

Kilopond: One kp. is the force acting on a mass of one kilogram at the normal acceleration of gravity.

Kilopond Metre: Physical work unit done on a bicycle ergometer during a specific period of time. It is the product

[illegible]

[illegible]

[illegible]

[illegible]

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[illegible]

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of the tension in kiloponds applied against the bicycle wheel and the distance covered by the wheel during one complete revolution of pedals multiplied by the number of revolutions per minute. Expressed in metres kilopond per minute (kpm/min.).

Maximal oxygen consumption ($M\dot{V}O_2$): The rate of oxygen consumption, reached at a point below exhaustion, when the cardio-respiratory mechanism can make no further adjustments to increasing work loads.

Oxygen consumption ($\dot{V}O_2$): Oxygen intake, oxygen uptake are synonomous; is the volume of oxygen (at $0^{\circ}C$, 760 mmHg, dry = STPD*) extracted from the inspired air, usually expressed as litres per minute or as a function of body weight (ml/kg/min.) *STPD = standard temperature and pressure, dry.

Oxygen pulse ($\dot{V}O_2/HR$): The amount of oxygen consumed per heart beat; expressed in ml./beat.

Physical work capacity (PWC): The ability of the individual to perform prolonged physical work, that is, the ability of the cardiopulmonary system to take up, transport and give off oxygen to the muscle tissues for the performance of physical work.

Pulmonary ventilation ($\dot{V}E$): The volume of air expired per minute and expressed in litres per minute at standard tempera-

ture and pressure, dry (STPD).

Respiratory quotient (R.Q.): The ratio of carbon dioxide volume produced to oxygen volume utilized during the same period of time (CO_2/O_2).

Submaximal and maximal work loads: This concept is individually specific and relative to maximal work capacity for a specified period of time. In this study a submaximal work load of 450 kpm corresponded to a heart rate of approximately 150 - 160 beats per minute.

Training: A regular regime of exercise that is carried out over a period of time and that encompasses the principle of overload.

Training heart rate in percentage: Is the % of the difference between the resting and maximal rates added to the resting heart rate value.

e.g. Maximum heart rate = 195 beats/min.
resting heart rate = 75 beats/min.
50% of the difference = 60 beats/min.
Training heart rate = 60 + 75 = 135 beats/min.

Training threshold or training stimulus: The physical stress required to elicit an improvement of an individual's cardiorespiratory system during physical training.

Ventilatory equivalent ($\dot{V}E/VO_2$): The ventilatory volume per litre of oxygen consumed per minute (VE/VO_2) at STPD.

Work load: Work performed against a fixed resistance and measured in kilopond meters per minute (kpm/min.).

CHAPTER II

REVIEW OF LITERATURE

GENERAL EFFECTS OF TRAINING UPON THE CARDIORESPIRATORY SYSTEM

In exhausting activity, such as in competitive sports, the intensity of exercise is circumscribed by the limits of the physiological functions involved. At any given time the capacity for supplying oxygen to the tissues is strictly limited. The primary objective of the physical training is to increase the physical performance through the improvement of the efficiency of the cardiorespiratory system and also the metabolic pathways. Many training regimes have been developed to improve this particular capacity in the last few years. These studies included wide variations of training designs with walking, jogging, and bicycling being analyzed the most frequently. It has become increasingly important though, to qualify and quantify the training programs so that an optimal improvement in physical fitness can be attained.

Knehr (69) studied the effects of a six month training program with fourteen sedentary subjects (middle aged). The maximum working capacity was measured on the

treadmill before, during and after this period of training. After two and six months of training, the $M\dot{V}O_2$ increased 5.5% (from 3.45 to 3.64 litres/min.) and 7% (from 3.45 to 3.69 litres/min.) respectively. During maximal work, the blood lactate concentration increased 18.4% (from 114 to 135 mg%) and the maximal heart rate was unchanged while the training increased the course of recovery heart rate. The maximal work load improved 60% (from 3786 kgm/min. to 6040 kgm/min.) due to training. The training regime was accompanied by a slight increase in weight, a decrease in resting pulse rate of five beats/min. (from 67 to 62 beats/min.) a slight decline in the respiratory rate and volume (from 6.23 to 5.59 litres/min.) at the resting level.

Cureton *et al*. (31) observed the changes in the cardiorespiratory system during eight weeks of physical training, followed by eight weeks of rest, and finally another eight weeks of physical training considerably harder than the first one. Six sedentary subjects (aged 28 to 47) participated in a training program for one hour a day, six days per week, which consisted of calisthenics, cross country running, and handball or squash games. The physical work capacity tests were conducted on the treadmill at the beginning and the end of each of the eight week periods. Over the first eight week training period, the $M\dot{V}O_2$ increased 35% (from 25 to 38.2 ml./kg./min.). The $M\dot{V}O_2$ levels

returned to approximately pre-training values after the eight week period of rest. Following the third eight week period of more intensive training, the $M\dot{V}O_2$ increased 93% (from 25 to 48.1 ml./kg./min.). Significant weight loss occurred over the program, which could have accounted for a portion of these large increases, but exact figures were not given so the precise contribution of the weight loss to the improvement of $M\dot{V}O_2$ cannot be determined.

Naughton and Balke (86) trained six sedentary men (aged 26 to 33 years) five days a week, thirty minutes a day, for sixteen weeks. Five subjects trained by running and one with a combination of daily tennis and calisthenics. Maximum oxygen consumption was measured on a treadmill before and after the training program. The $M\dot{V}O_2$ increased over the training period by 43% (from 31.6 to 45.3ml./kg./min.) even though body weight decreased by only 2.6% (from 79.5 to 77.4kg.). The work capacity on the treadmill at a constant speed of 3.4 m.p.h. increased from 12 to 20% grade over the training period. The heart rate at maximal load did not change with training (180 beats/min.) but decreased at a given submaximal work load (from 160 to 140 beats/min. at 10% grade) after the sixteen weeks. This large improvement in $M\dot{V}O_2$ could be explained by a relatively low initial work capacity level.

Naughton and Nagle (87) trained eighteen sedentary

men (mean age 41 years), thirty minutes a day, three days a week over a period of seven months. The training exercises included warming up, calisthenics and interval running with increasing intensity throughout the program. A pre and post training tests on treadmill revealed an increase of 15.3% (from 31.6 to 36.1ml./kg./min.) in maximum oxygen consumption. The maximal heart rate was unchanged, and maximum ventilation increased from 69 to 76 litres per minute after the training period.

In Cumming's study (28), the maximum oxygen uptake of six boys and six girls, 13 to 16 years of age, showed no change with twice daily measurements over a six day period during a track camp where intensive physical training was carried out. The camp program provided a one week period of education and competition with emphasis on circuit running and interval training, the boys and girls were required to run a total distance of up to 15 miles each day. Over the 6 days, submaximum pulse rate declined 6 beats/min. for a constant load, and maximum pulse rate declined 7 beats/min. The maximum oxygen uptake increased from 3.86 to 4.02 litres/min., but this was not statistically significant. There was a tendency for submaximum exercise pulse rates to decline during training before any increase in aerobic capacity occurred.

Swenson *et al*. (113) trained ten sedentary Caucasian

males (aged between 36 and 56 years) five days a week, approximately one hour per day for eight weeks. Training consisted of strength and flexibility developing calisthenics weight training and running. Running was the major aspect of the program; the distance and the intensity of running were progressively increased during the training period. The physical work capacity was evaluated on the treadmill prior to and following the eight week training. At a given submaximal work load (3m.p.h., 5% grade) the heart rate decreased from 141 to 115 beats/min., after the training. Also, at a given heart rate of 160 beats/min., the respiratory rate increased from 26 to 29 breaths/min. and the tidal volume increased from 2.43 to 2.72 litres over the training regime. No values were reported at maximal work load.

Williams (122) investigated the effect of training on aerobic and anaerobic metabolism in thirteen Bantu male subjects. The training regime, consisting of prolonged daily exercise (4 hours) at aerobic levels of work followed by exhaustive runs at maximal effort, lasted from four to sixteen weeks. The results demonstrated very clearly that a regime of training can influence both the maximum oxygen intake and the level of oxygen intake at which "*excess lactate" appears in the blood. The mean maximum oxygen intake increased 7% (from 2.8 to 3.1 litres/min.) over the sixteen week training period. However, the mean level of

oxygen intake, expressed as a percentage of the maximum value, at which "*excess lactate" appeared, increased from 46 to 62 per cent. Williams et al. (121-122) concluded that in untrained individuals the onset of anaerobic metabolism occurred at 40-50 per cent of the maximum oxygen intake, in trained individuals at 55-60 per cent and in the exceptionally well trained men at about 70 per cent. (*Excess lactate was defined by Williams (122) as the level at which the blood lactate concentration starts to accumulate over the resting concentration level.)

Hanson et al. (53) trained twenty five men (aged 40 to 49 years) for one to one and a half hours per day, three days a week over a period of seven months. The basic training program consisted of muscle stretching and flexibility exercises, calisthenics, running, volley-ball, basketball, badminton and paddleball games. The maximum oxygen consumption of the subjects were evaluated on the treadmill. Following the training period, the $M\dot{V}O_2$ increased 18% (from 2.60 to 3.07 litres/min.) the maximal working capacity improved 22% (from 868 to 1063kgm/min.) and maximal heart rate decreased from 173 to 169 beats/min. The increase in $M\dot{V}O_2$ was partly attributed to a 14% increase in stroke volume. Work load capacities at heart rates of 130, 150, and 170 beats/min. were also augmented (110, 215

and 245kgm/min. respectively).

In Ribisl's study (90), fifteen sedentary subjects, (average age 40.2 years) participated in a five month endurance running program. The training program involved calisthenics, interval and cross country running, three days a week and thirty five minutes per session. An approximation of the energy requirement for the training exercises was 300 kcal/hr. in the first month and was increased progressively to reach about 750 kcal/hr. in the final month. Maximum oxygen consumption was evaluated on a treadmill before and after the training period and showed a 14% improvement (from 40.1 to 45.5 ml./kg./min.) over the 5 months. The maximal ventilatory volume increased from 129 to 143 litres/min., and the maximum oxygen pulse improved from 19.0 to 21.2 ml/beat while the maximum heart rate was unchanged following training.

Saltin _et_ _al_. (97) carried out extensive studies on the effect of a twenty day period of bed rest followed by fifty five days of physical training with five males, aged 19 to 21 years. Three of the five subjects had previously been sedentary, and two of them had been physically active. The values after bed rest and after physical training were both compared with the initial control values. The training program consisted of interval and continuous running,

one hour per day, six days a week. The maximum oxygen uptake increased from 2.52 to 3.41 litres/min. (33% increase, attributed to the low initial fitness level of the sedentary subjects) and from 4.48 to 4.65 litres/min. (4%) in the previously active subjects over the training period. The improvement in $M\dot{V}O_2$ of the sedentary subjects could be attributed to an increase in stroke volume (17%) and an increase in A-VO_2 difference (5.6%). Maximal heart rate remained constant, and mean ventilatory volume during maximal work increased from 129 to 156 litres/min. after training. The increase was attributed to an increase in respiratory rate (from 43 to 53 breaths/min.) as the tidal volume was unchanged. The ventilatory equivalent (VE/VO_2) did not change with training. At a given submaximal work load requiring 1.5 litres of oxygen per min., the heart rate decreased from 129 to 115 beats/min.

Cunningham _et_ _al_. (29) studied aerobic and anaerobic metabolism during a short exhaustive run in eight males (aged 23 to 41 years) before and after a six week training program. The short exhaustive run was performed on a treadmill at a speed of 8 m.p.h. and a grade of 20%; run times ranged from 36 to 66 seconds. The training program consisted of interval sprints of 220 yards and distance runs of 2 miles, 5 days per week. The training resulted in a 23% increase in run time for the short exhaustive run.

The net oxygen uptake was 16% higher after training (from 3.1 to 3.7 litres/min.). Compared to the pretraining test results, there was a 17% increase in blood lactate concentration (from 96 to 118mg%), a 9% increase in oxygen debt (from 6.1 to 6.9 litres/min.) and a 19% increase in ventilation (from 135 to 148 litres/min.) during maximal work after the training.

Vrijens (118) compared eleven volunteer adolescents (mean age 16.7 years) with nine students (mean age 17.1 years) in a scheduled physical education class. The two groups were considered to be equivalent in anthropometrical and functional tests. The experimental group participated in a circuit training (10 exercises) regimen in addition to the regular physical education program for a period of six weeks, with three training sessions per week. The circuit was performed according to the interval principle. The intensity of each exercise (bench-stepping, pull-up, sit up, rope climb, etc.) was fixed at 90% of the individual's performance capacity. After the six weeks of training, the maximum oxygen consumption increased 14% (from 3.1 to 3.6 litres/min.), the maximum work loads increased from 283 to 300 watts, the maximum ventilatory volume improved from 98.6 to 111.6 litres/min. (13%) and finally the improvement of the oxygen pulse was 1.9ml./beat (from 16.2 to 18.1 ml./beat). The control group showed no significant gain in any of these tests.

Ekblom (41) trained six boys, all 11 years old, over a period of six months, and compared them to a control group. The training program consisted of interval and distance runnings, weight training and ball games, twice a week; each session lasted 45 to 60 minutes. Maximum oxygen consumption was determined before and after the training period on a bicycle ergometer. The $M\dot{V}O_2$ of the training group improved from 2.15 to 2.48 litres/min. (15%) or from 53.9 to 59.4 ml/kg./min., but was unchanged in the control group. The maximum ventilatory volume increased from 68 to 80.4 litres/min. (32%) and the maximum heart rate decreased from 204 to 199 beats/min. after the training program. However, there was no change in blood lactate concentration at maximal work after training. At a given submaximal work rate, the heart rate decreased from 148 to 139 beats/min. Five boys from the training group continued training for a further twenty-six months, and it was then found that $M\dot{V}O_2$ increased in total by 55% (from 2.15 to 3.41 litres/min.) which was more than expected from the age-dependent increase in terms of body weight.

In Ekblom's study (42), submaximal and maximal work was performed by eight male students (aged from 19 to 27 years), on a bicycle ergometer before and after sixteen weeks of physical training. The physical conditioning program consisted of either sprints, interval or long-distance

running, three times a week. During the distance running the heart rates varied from 130 and 170 beats/min. and during the sprint, this fluctuation was from 150 and 170 beats/min. After the training period, the average maximum oxygen uptake increased 16.2%, or from 3.15 to 3.68 litres per minute; the maximum ventilation increased from 115 to 132 litres/min. In addition, the blood lactate concentration increased from 108 to 135mg% during maximal work, but the maximal heart rate did not change as a result of the training period. The improvement of $M\dot{V}O_2$ was attributed to increased maximum cardiac output and increased venous arterio oxygen difference. The total work output that could be performed at the exhaustive work level increased 25% (from 1406 to 1759 kpm). At a given submaximal oxygen uptake, heart rate decreased from 170 to 144 beats per minute, and blood lactate concentration also decreased from 76.5 to 51.3mg% after training.

Pollock <u>et al</u>. (88) divided nineteen men, between 28-39 years of age, into two training groups and one control group. The first group exercised two days a week, and the second group four days a week for twenty weeks. The training program consisted of continuous walking, jogging or running; each session lasted 30 minutes. The maximum working capacity was determined on the treadmill before and after the training period. The two training groups respectively im-

proved their $\dot{M}VO_2$ from 37.7 to 44.0 ml/kg/min. (17%), and from 36.7 to 49.3 ml/kg/min. (35%); maximum pulmonary ventilation from 127.2 to 140.8 litres/min. (10%) and from 128.9 to 142.6 litres/min. (11%) and their maximum oxygen pulse from 16.6 to 19.8 ml/beat and from 16.4 to 21.6 ml/beat. The maximum heart rate decreased from 186 to 181 beats/min. for group 1 and from 187 to 176 beats/min. for group 2. No values were reported at a given submaximal work load before and after the training period.

In Hartley's *et al.* study (54), fifteen previously sedentary men (38 to 55 years old) participated in a training program which consisted of running for one to one and a half hours a week for eight to ten weeks. A pre and post training maximal work capacity test was performed on a bicycle ergometer. Maximum oxygen uptake improved from 2.68 to 3.06 litres/min., i.e. 14%. This increase was due to a 13% increase in cardiac output since arteriovenous oxygen difference did not change. The maximum heart rate decreased by 6 (from 182 to 176 beats/min.). Thus, the improvement in cardiac output at maximal loads was due to increased stroke volume (16%). At a given submaximal exercise, the heart rate was 8-17 beats/min. lower after the training period. In addition, blood lactate concentration was lower at submaximal and higher at maximal work loads after training.

Saltin et al. (99) observed forty-two subjects, aged from 34 to 50 years, before and after an eight to ten week conditioning program. The training program involved walking, jogging, strength exercises and long distance running, approximately 30 minutes per day, two to three days per week. Twice a week the activity was intermittent while the third training session was continuous. In the intermittent exercise, heart rate approached maximal value, while during the continous running, heart rate varied between 60 and 65% of the maximal heart rate. The $M\dot{V}O_2$ was evaluated on a bicycle ergometer and improved 18% (from 2.89 to 3.44 litres/min.) over the training period. Maximum pulmonary ventilation increased 15% (from 112 to 128 litres/min.); this increase was brought about by an increase in the respiratory rate from 42 to 46 breaths/min. as the tidal volume remained the same. The maximum heart rate decreased by 8 beats/min. due to the training, and blood lactate concentration at maximal work was increased from 115.2 to 126mg% (9%). At a given submaximal work load requiring 2.1 litres of $\dot{V}O_2$, the heart rate decreased from 155 to 138 beats/min. and blood lactate concentration decreased from 56.7 to 42.3 mg% over the training period. The ratio between pumonary ventilation and oxygen uptake ($\dot{V}E/\dot{V}O_2$) was unchanged both at submaximal and at maximal exercises.

Wilmore (123) divided fifty five men (aged 17-59)

into two groups for a ten week program of jogging; one group trained 12 minutes/day, three days/week, and the other group trained 24 minutes/day, three days/week. The jogging was performed either on an outdoor (440 yards) or an indoor (220 yards) track; daily records were kept by each subject indicating both the duration and the distance of the run. A pre and post training test was administered on a bicycle ergometer. With training, both groups demonstrated significant increases in: $M\dot{V}O_2$ (from 41.56 to 44.03 ml/kg/min. for the 12min/day group, and from 42.96 to 47.12 ml/kg/min. for the 24min/day group); oxygen pulse (from 17.80 to 19.73 and from 18.29 to 21.37 ml/beat); and significant decreases in resting heart rate (from 75 to 66, and 70 to 62 beats/min.) and maximal heart rate (from 186 to 179, and 182 to 177 beats/min.) for the 12 min/day group and the 24 min./day group respectively. A decrease in weight and increase in total work, and maximum ventilatory volume (from 146.1 to 152.3 litres/min.) were found only in the 24 minute group while the 24 minute group generally demonstrated changes in the desired direction of greater magnitude, the differences between these two groups relative to their respective changes were not statistically significant with the exception of the residual volume. In addition, age did not appear to influence the degree of physiological changes resulting from this training program.

Seigel _et al_. (101) evaluated the effects of a fifteen week training program in nine blind men (32 to 59 years old). All subjects were sedentary with a stable activity pattern. Training sessions were held three times per week and consisted of four 3 minute exercise periods on a bicycle ergometer, each followed by a rest period of equal duration. The training exercise elicited heart rates of approximately 27 beats/min. below individual maximal heart rate. Maximum oxygen uptake increased 19% (from 24.0 to 28.5 ml/kg/min.) over the 15 weeks of training. The initial seven weeks of training resulted in an increase in $M\dot{V}O_2$ by 10% above control levels. Maximum heart rate did not change with training (167 before and 169 beats/min. after the fifteen weeks). The blood lactate levels during maximal work were unchanged over this training period (109 (control) and 113 (training) mg%). The maximal work load increased 39% (from 626 to 790 kpm/min.) over the fifteen week training period.

Pollock _et al_. (89) trained sixteen sedentary men between 40 and 56 years of age for forty minutes per day, four times a week over a period of twenty weeks. The training program involved walking, and the intensity progressed from 2.5 miles during the first week to 3.25 miles during weeks 16 to 20. The subjects were divided into ability groups and were encouraged to walk as far as possible

in the prescribed time period. The maximum oxygen consumption was measured prior to and following the training period and showed an increase of 28% (from 2.30 to 2.94 litres/min.); also, the pulmonary ventilation increased 15% (from 86.9 to 102.6 litres/min. STPD), and oxygen pulse improved 21% (from 13.8 to 17.4 ml/beats) during maximal work. Maximum heart rate and resting heart rate did not change with training. Body composition showed a reduction in total body weight (1.3 kg.) and per cent fat (1.1%). However, the training period decreased mile walk time from 774 to 664 sec. (17%).

Webster (119) evaluated the changes in cardiorespiratory endurance after a six week jogging program. Eighty high school students, aged 14-17, were divided into four groups; group l jogged 3/8 of a mile, group ll, 3/4 of a mile, group lll, l mile, and group lV acted as a control. Jogging was carried out daily and the intensity increased weekly. Changes in aerobic power were determined by employing the twelve-minute run walk and the Astrand-Ryhming nomogram test. Results indicated that all three experimental groups exhibited a significant increase in predicted maximal oxygen consumption values. The improvement was 8% (from 41.35 to 44.90 ml/kg/min.), 12% (from 39.25 to 45.30 ml/kg/min.) and 12% (from 40.30 to 46.45 ml/kg/min.) for the group l, ll and lll respectively. No significant difference in $M\dot{V}O_2$, however, was found between the three training groups following

the jogging program.

Daniels et al. (32) studied fourteen boys, 10 to 15 years of age, during twenty-two months of distance running training. Submaximum and maximum oxygen consumption were determined on the bicycle ergometer. Over the twenty-two month period, there was an increase of 11.2 cm. in height and 9.2 kg. in weight. The 22% improvement in maximum oxygen consumption accompanied by an increase of 23% in weight resulted in essentially no change in maximum oxygen consumption relative to body weight. The maximum ventilatory volume increased from 85 to 103 litres per minute, probably caused by the 23% increase of subject's weight. The decrease in oxygen consumption from 52.2 to 45.5 ml/kg/min. at a given submaximal work load was attributed to an increase in mechanical efficiency. From this study it is practically impossible to evaluate any training effects because the author failed to use a control group and therefore the results confused growth and training effects. The intensity of training also was not controlled.

It has been pointed out that physical activity ranging from repeated work period of a few minutes duration up to hours of moderate work may involve, in major part, the oxygen transporting system and thereby induce a training effect. The efficiency of the aerobic metabolism is demonstrated by an increase in maximum oxygen consumption ranging from 5% to

35%, which is related to the intensity, frequency and duration of the training and also to the age of the subjects and their initial fitness level. The improvement of the anaerobic metabolism is noted by a greater tolerance to lactic acid in the blood. Most of these studies have been carried out with sedentary or active adult subjects; it might be appropriate to expect an improvement in the same way with children.

TRAINING THRESHOLD

The selection of an optimum training regime has obvious practical applications, both in the preparation of athletes for specific events and in the promotion of an increased level of fitness within the community. Current literature relating to the respective importance of intensity, frequency and duration of exercise as training stimuli suggests that the intensity is the major training stimulus. Some authors stressed the existence of a threshold below which no training effect occurred, others have found quite mild exercise to be effective.

Karvonen (67, 68) contended that to improve the exercise tolerance of the cardiovascular system the heart rate during training has to be more than 60 percent of the available range from rest to the maximum attainable by running. Karvonen (67) trained six subjects, aged from 20

to 23 years, by running at different speeds on a horizontal treadmill 30 minutes daily, four to five times a week over a period of four weeks. The author noticed that the heart rate during training has to be above approximately 140 beats per minute in order to produce a decrease in the working heart rate. No other values were taken.

Hollmann and Venrath (57) obtained similar results with middle-age subjects; if the heart rate during a training program, consisting of a 30 minute ergometer ride daily for five weeks, was lower than 130 beats/min., there was no significant increase in maximum oxygen intake. However, if the heart rate during training was above 130 beats/min., there was an increase of aerobic capacity in the same period of time. Hollmann (57), also, studied six previously sedentary subjects who trained four times a week, 20 to 30 min. each time during a period of ten weeks. During the first week the training heart rate was about 125 beats/min. After five weeks of training the maximum oxygen uptake increased from 2.90 to 3.07 litres, a 6% increase; but not significantly different. The resting heart rate dropped from 73 to 63 beats/min. During the subsequent five weeks, the training intensity was increased to elicit a heart rate from 150 to 180 beats/min. The maximum oxygen uptake increased by 21% (from 2.90 to 3.51 litres/min.). The resting heart rate decreased to 59 beats/min.

Durnin *et al*. (38) attempted to measure whether there was an improvement in physical fitness through varying degrees of exercise for a training period of only ten days duration. Forty-four untrained men (aged 18-22) were divided into four groups; one control group and three groups walked 10km., 20km and 30km daily respectively; "fitness" was assessed by various physiological measurements during a standardized physical test on the treadmill. The test was done before, during and after the period of training. The group of men walking 20km daily showed the most marked improvement in "fitness" with a significant lowering of pulmonary ventilation (from 61.0 to 55.3 litres/min. BTPS), oxygen consumption (from 2.39 to 2.06 litres/min.) and heart rate (from 172 to 156 beats/min.) at a given submaximal workload. No significant differences were found in the other two groups after training. The author mentioned that the last group (30km) had much more ambiguous results and it is possible that the exercise was too severe for their initial level of fitness. During these walks eliciting a heart rate of about 120-130 beats/min., it seems, within certain limits, that the duration of work should be an important factor in improving work capacity. They concluded that walks eliciting heart rates of 120-130 beats/min. resulted in a significant decrease in heart rate for a given submaximal work.

Roskamm (93) compared the effects of different training intensities with eighty soldiers, aged from 18 to 25 years. They were divided into four groups: three of the four groups trained 30 minutes daily, five days per week for four weeks. The total amount of work done on the bicycle ergometer was the same in all these groups. One group trained continuously with a work load which brought the heart rate to 70% of the difference between resting and maximal rates. A second group trained at alternate work loads; for 1 minute, the load was 50% higher than the first group, followed by a 1 minute period during which the load was 50% lower. The third group performed a similar training with various work loads, each period was extended to 2.5 minutes. It was found that all training groups improved their maximal working capacity compared to the control group. Almost all the trained soldiers had an increase of more than 10%. The decrease in heart rate at a standard load (100 watts) was more pronounced for the subjects training continuously at 70%. The author concluded that training at a heart rate of 70% of the difference between resting and maximal rates was effective to improve physical work capacity and submaximal heart rate.

Sharkey and Holleman (103) divided sixteen college men (aged 18-19) into three training groups and one control group in a study of selected cardiorespiratory adaptations

to six weeks of training exercises eliciting either 120, 150 or 180 heart rates. Training consisted of walking on the motor driven treadmill for 10 minutes a day, three days per week. The Astrand-Ryhming nomogram prediction of aerobic capacity showed significant changes due to training. Analysis of group differences revealed that the 180 and the 150 training groups improved significantly in $M\dot{V}O_2$, while the 120 and control groups did not change with training. These results indicated the need for a heart rate above 150 beats/min. during exercise before a training effect is elicited.

Shephard (105) compared three training programs using three independant variables: intensity, duration and frequency of training. Thirty nine sedentary subjects, aged from 19-41 years, were assigned to one of three intensities (39%, 65% and 96% of the individual's aerobic capacity) for one of three durations (5, 10 and 20 minutes per session) for one of three frequencies (1, 3 or 5 times per week) for a six week training period. The maximum oxygen uptake improved from 35.6 to 37.4ml/kg/min. (5%) in the lowest intensity group and from 35.6 to 40 ml/kg/min. (12%) in the highest intensity group. He found intensity as the main factor influencing the training effect, and that this intensity must be above 65% of the individual's aerobic capacity.

Molloy (82) determined the heart rate response to varied intensities of training. Twenty four males (aged 17-24) participated in a six week training program consisting of a thirty minute bicycle ergometer ride, three times per week. The subjects trained at a work intensity corresponding to a pre-determined heart rate; group 1 trained at 155 bpm, group 11 at 140 bpm and group III at 125 bpm. The pre and post training tests predicting the aerobic capacity were conducted through the Astrand-Ryhming nomogram. He found a significant difference in predicted maximum oxygen uptake, over the six week training period. The values increased from 38.5 to 48.5 ml/kg/min., from 37.8 to 46 ml/kg/min. and from 44.5 to 49 ml/kg/min. for the 155 bpm, 140 bpm and 125 bpm groups respectively. In terms of net aerobic improvement, the 155 bpm and 140 bpm groups differed significantly from the 125 bpm and control groups. No other differences were shown to be significant. The author concluded that a thirty minute training session three times per week for six weeks results in a significant training effect on the exercise heart rate, only if the intensity of training exceeds a rather high level; for this study, the critical level fell somewhere within a pulse rate range of 125-140 bpm.

Sharkey (102) attempted to control total work done in a training program and to vary the intensity and duration

of the exercise. Thirty six male college students, aged from 18 to 24 years, were assigned to either 7500 kpm or 15,000 kpm of total work for each training session at 130, 150 and 170 heart rates. The training program was conducted on a bicycle ergometer, three days per week over a period of six weeks. Pre-post training differences did not reveal significant intensity, duration or interaction effects. No attempt was made to equate groups on initial fitness levels, these large variations could account for the non-significant differences.

Wenger (120) attempted to determine whether intensity or duration of training sessions is the primary determinant of endurance fitness if the total work performed during training and the initial fitness levels within each group were equated. Thirty six subjects (mean age 27.9 years) were divided into three groups: the first group trained at 100% of the workload which produces $M\dot{V}O_2$; the second group trained at 60% of the maximal work load and the third group acted as a control. The training was conducted on a bicycle ergometer and consisted of three sessions per week for seven weeks. Following training, the maximum oxygen consumption increased by 35% (from 39.5 to 53.3 ml/kg/min.) and 25% (from 39.3 to 48.9 ml/kg/min.) for the T 100% and T 60% groups respectively. The blood lactate concentration increased 23%

and 20% with training in the T 100% and T 60% respectively. After training also, significant decreases in heart rate, ventilatory volume and blood lactate concentration occurred for both training groups over the control at the workload which produced $M\dot{V}O_2$ on the initial test. However, there was no significant difference at this workload between the two training groups. The author concluded that any intensity of training (from 60% up to 100% of $M\dot{V}O_2$) would be equally suitable in reducing cardiac work at submaximal workloads. However, to improve maximum oxygen intake, he suggested that intensity of the training is the primary contributor in improving the oxygen transport system. The increased intensity seemed to improve, to a greater extent, the capacity to do physical work.

Faria (43) investigated forty untrained healthy males, aged from 18 to 24 years, in a study of selected cardiovascular adaptations to four weeks of training exercises eliciting heart rates either 120-130, 140-150, or 160-170 beats/min. Training consisted of bench stepping until the assigned heart rate was reached, five days a week. Significant differences were found in the analysis of the pre-post 180 work capacity test (PWC-180). Analysis of group differences revealed that the 140-150 and 160-170 training improvement was significantly different from the other group. No other differences were statistically significant. The study sup-

ported the hypothesis that when training to improve one's physical capacity to do work, the severity of the training effort is related to,but not proportional to, intensity of the training.

Most of the studies have suggested that the intensity of training is the major stimulus in improving the individual's physical work capacity. It has been possible to quantify the relationship of the intensity of training to the level of endurance acquired. These studies reported the possibility of an optimum response to a training threshold. Some studies demonstrated that training at a heart rate of 115-125 beats per minute resulted in a lower heart rate at rest and during submaximal exercise; further investigation indicated that training at 150-160 beats per minute resulted in both heart rate and maximum oxygen, consumption increases. A consensus from these studies suggests that to improve the exercise tolerance of the cardiorespiratory system in adults the heart rate during the exercise must be increased at least above 60% of the difference between the resting and maximal rates, corresponding to approximately 150 beats per minute. In children this training threshold could be higher than in adults probably due to their slightly higher maximal heart rate and also because they are more physically active than adult individuals. On the other hand, this threshold can

be influenced by the seasons; the present study was carried on during the winter time when the children were not engaged in bicycle riding.

MAXIMAL WORK CAPACITY VALUES OF CHILDREN (TABLE I)

Maximum oxygen consumption is said to be the best single measure of physical fitness (9, 80), and has been used during increasing physical work as a maximal test in population studies as well as to assess the work capacity of athletes and those with heart diseases. Aging factors in maximal test are minimized by the requirement for the subjects to continue until the heart rate reaches the maximum for the age group under study. The physical work capacity of children has been studied in some exercise tests, such as running, stepping, bicycling, jumping, etc. Table I summarizes some cardiorespiratory values of children during maximal work on the bicycle ergometer or treadmill.

VALUES OF OXYGEN UPTAKE, HEART RATE, VENTILATION, WORK LOAD AND LACTATE DURING MAXIMAL TEST IN CHILDREN, AGED 11-13 YEARS

	N	WEIGHT kg	HEIGHT cm	WORK LOAD kgm/min	$\dot{M}VO_2$ l/min	$\dot{M}VO_2$ ml/kg/min	HR b/min	V_e l/min	LACTATE mg%	PULSE O_2 cc/beat	RQ
Robinson (1938) USA	21	42.5	151	-	2.04	49.6	204 ±6	73	58.5	-	
Morse *et al.* (1949) USA	17	38.0	147	-	1.74	45.8 ±3.7	192 ±8	60.8	63.3	-	
Cumming *et al.* (1963) WINNIPEG	22	36.0	144	658	1.56	44.1	201 ±7	-	-	7.5	
Cumming *et al.* (1967) WINNIPEG	20	44.7	152	835	2.36	53.8 ±6.4	202 ±8	-	-	-	
Kramer *et al.* (1964) USA	26	44.1	153	660	1.94 ±0.29	46.5 ±7.8	190 ±10	68.3	-	-	
Sprynarova (1965) PRAGUE	114	40.7	149.7	-	2.05 ±0.33	50.5 ±5.1	196 ±8	-	-	8.0	
Sprynarova (1966) PRAGUE	35	41.3	148.6	-	2.01 ±0.34	49.1 ±6.4	194 ±10	51	-	-	
Shephard *et al.* (1969) TORONTO	25	39.5	-	-	1.81 ±0.33	47.5 ±7.02	193 ±10	65.3	78.	-	
Gadhoke *et al.* (1969) LONDON	40	44.0	151	750	2.24	51.1 ±6.2	191 ±11	58	73	-	
Bailey, D.A. (1970) SASKATOON	112	39.4	-	Treadmill	2.22	56.9	204	59.7	-	10.88	0.93
Means	43	41.0	150	726	2.0	49.5	196.7	62.3	68.2	8.8	0.93

CHAPTER III

METHODS AND PROCEDURES

SAMPLE

Thirty six volunteer boys between the ages of eleven and thirteen (mean age 12.5 years), participated in the study. All boys resided in Edmonton and were students at the College Saint-Jean.

TESTING CONDITIONS

The testing was done in a temperature of 23±2°C in a class room of the College Saint-Jean; the humidity was not controlled. All the subjects reported to the testing room for the initial maximum oxygen consumption test during the three days prior to the training program. They were then tested again at about the same time of day during the three days following the six week training period.

CALIBRATION AND DESCRIPTION OF THE INSTRUMENTS

The test gases used to calibrate the oxygen and carbon dioxide analysers were checked with a Micro Scholander Gas Analysis Apparatus according to the Scholander technique described by Consolazio, Johnson and Pecora (23). The Beckman Model E-2 oxygen analyser and the Godart Capnograph

carbon dioxide analyser were then calibrated with the test gases in the morning and at noon of every testing day. The Beckman is an instrument analysis system measuring the magnetic susceptibility of the gas mixture with a magnetic torsion balance. Since oxygen is strongly attracted into a magnetic field and other expired gases are not, accurate oxygen analysis can be made even though other gases are present in the sample. The measuring principle of the Godart Capnograph is the absorption of infra-red rays by carbon dioxide gas. The carbon dioxide content of the gas being analyzed is read directly in percent from the scale. The correction factor (from barometric pressure and temperature) for converting the gas volume to STPD was taken twice a day during the testing periods.

COLLECTION AND ANALYSIS OF GASES

The breathing apparatus which consisted of a Collins Triple J valve attached to an adjustable helmet, was fitted to the subject. A rubber mouth-piece was fixed to the triple J valve and a nose-clip occluded the nasal passages. The output of the triple J valve was connected by way of a flexible, low-resistant plastic hose to a Douglas bag. A two way metal valve attached to the neck of each Douglas bag permitted the collection of the expired air at the desired time. The collected air was analysed for oxygen content with a Beckman Model E-2 analyser and with a Godart Capnograph for

the carbon dioxide. The volume of expired air was measured in a Parkinson Cowan Dry Spirometer Type CD4. An Olivetti 101 desk computer was pre-programmed with the formula from Consolazio, Johnson and Pecora (23), so to give an output of the following parameters:

a) % of oxygen in the expired air
b) volume of expired air (litres per minute,STPD)
c) volume of inspired air (litres per minute,STPD)
d) oxygen consumption (liters per minute,STPD)
e) oxygen consumption (ml per kg per minute,STPD)

BLOOD SAMPLING AND ANALYSIS

Between 45 and 60 seconds after each work load, blood was sampled from a finger tip of a hand pre-heated in a water bath kept at 45-47^{o}C. Blood samples collected were analyzed for lactic acid content according to the enzymatic micromethod described by Mohme-Lundholm, Svedmyr and Vanos (81). The standard error for the micromethod to determine the lactic acid content of finger-tip blood is 4 percent. (See Appendix A for the enzymatic micromethod's description.)

TEST PROCEDURES

Subjects came to the testing room and their weight and height were taken. After a brief explanation of the test and a period of pedalling on the Monarch bicycle ergometer, the three electrodes were attached and connected via

patient leads to a Sanborn Electrocardiography preamplifier. The head harness and Collins triple J valve were attached to the subject and the nose clip put in place. A maximum oxygen consumption test was then performed according to the method of Astrand (10) and modified by Macnab, Conger and Taylor (76). This test consisted of a series of work periods lasting four minutes each at different work loads with a five minute rest between each period. Heart rates were recorded and expired air was collected during the fourth minute of work at each work load.

All the subjects performed a specific submaximal workload equal to 450kpm (1.5kp, 50 revolutions per minute). During the subsequent working periods, the work load was increased until the students reach their maximum oxygen consumption corresponding to a heart rate of 195±8 beats/ min. Blood samples were taken between 45 and 60 seconds following each work load.

The work loads during the post training test included the same submaximal work load (450kpm) and then further increases up to the new maximum load for the training groups. The control subjects, however, worked at the same loads as for the initial test and only exceeded their maximum if the heart rate was lower than the maximal heart rate reached during the first test.

ASSIGNING OF SUBJECTS TO THE TRAINING PROGRAM

Following the pre-training test, all subjects were ranked according to their maximum oxygen consumption expressed in ml per kg per minute. They were then divided into three blocks; the twelve subjects from each block were then randomly assigned to either of four treatment groups:

a) training group (T1) trained at a heart rate of 170-180 beats/min. corresponding approximately to 75-85% of the difference between maximal and resting heart rates.

b) training group (T2) trained at a heart rate of 150-160 beats/min. corresponding approximately to 60-70% of the difference between maximal and resting heart rates.

c) training group (T3) trained at a heart rate of 130-140 beats/min. corresponding approximately to 45 to 55% of the difference between maximal and resting heart rates.

d) control group (T4) who were asked to maintain their same activity pattern for six weeks.

Thus, there were nine subjects in each treatment group consisting of three subjects from each of the three blocks. The group means on maximum oxygen consumption (ml per kg per minute) were therefore equated:

a) T1 = 46.68 ml per kg per minute
b) T2 = 47.44 ml per kg per minute
c) T3 = 46.56 ml per kg per minute
d) T4 = 45.66 ml per kg per minute

TRAINING PROGRAM

Training was performed on a Monarch bicycle ergometer three times per week for six weeks at a work load sufficient to elicit heart rates of either 170-180, 150-160 or 130-140 beats/minute, each session lasting 12 minutes. This training session duration was selected arbitrarily. Adjustment of the work load to maintain the specified heart rate was monitored during the first training session of each week by using an ECG recorder. The subjects in each training group started at different loads depending on their physical working capacity. The work load required to elevate the pulse rate to the pre-determined training rate became the subjects's training work load for the following two sessions in the same week. Heart rates were also determined by carotid or brachial artery palpation during these two training sessions; this served as a rough check on the assigned training load.

STATISTICAL PROCEDURES AND EXPERIMENTAL DESIGN

A 4X3X2 factorial design (fixed model) with repeated measures on factor C was used (Winer (124)). The four levels of factor A were the treatments:

a) training at 170-180 heart rate
b) training at 150-160 heart rate
c) training at 130-140 heart rate
d) contrcl

The three levels of factor B (initial fitness level) were the three blocks into which the subjects had been assigned according to their initial $M\dot{V}O_2$ values:

a) highest fitness level
b) medium fitness level
c) lowest fitness level

The two levels of factor C were the:

a) pre-training test values
b) post-training test values

STATISTICAL ANALYSIS

The data of each parameter were analysed initially by a three way analysis of variance with repeated measures as discussed by Winer (124). The 4X3X2 factorial design was described previously and is summarized in Appendix F. If significant F ratios were obtained, the data was plotted and an objective decision made on which simple main effects were to be tested. Where F ratios for simple main effects were significant, a Newman-Keuls test was used as a comparison between means (124). However, since the groups were equated on $M\dot{V}O_2$ relative to body weight and not on all parameters,if F ratios for simple main effects were significant at the pre-training test, a Scheffe Contrast test (124) was used between mean differences (pre-training values - post training values) to determine in each group if the

improvements with training were significant. The two significant levels ($P < .01$; $P < .05$) were used. All computations were done via the IBM 360 computer at the University of Alberta.

CHAPTER IV

RESULTS AND DISCUSSION

The physical characteristics of the subjects are reported in Table II. The age average of the subjects was 12.5 years (ranging from 11 to 13 years). The mean body weight was 40.72 kg before the training and 41.57 kg after the six week training program (Figure 1), and the mean height was 152.8 cm before and 153.4 cm after the training period.

RESULTS AT SUBMAXIMAL WORK LOAD (450 kpm per min.)

The pre and post training values for the various physiological parameters are reported in Table III (mean and S.D. for each treatment group). The statistical analysis of each parameter is summarized in the Appendix B.

Heart Rate

Following the six week training program, the heart rate at a given submaximal work load (450 kpm per minute) decreased in the three training groups compared to the control group. The heart rate decreased 15.78, 13.67 and 12.12 beats per minute for the T1, T2 and T3 training groups

TABLE II

CHARACTERISTICS OF THE SUBJECTS

(MEANS AND STANDARD DEVIATIONS)

Groups	Age (years)	Weight (kg)		Height (cm)	
		Pre	Post	Pre	Post
T1 (170-180) (N=9)	12.7	44.14 ±8.91	45.05 ±8.88	157.8 ±19.4	158.1 ±19.5
T2 (150-160) (N=9)	12.4	39.40 ±7.50	40.16 ±7.53	149.0 ±23.6	149.5 ±23.6
T3 (130-140) (N=9)	12.6	36.31 ±8.11	36.82 ±8.08	148.3 ±15.9	149.2 ±16.0
T4 (control) (N=9)	12.6	43.03 ±9.08	44.24 ±9.08	156.2 ±17.2	156.7 ±17.4
Grand Mean	12.5	40.72	41.57	152.8	153.4

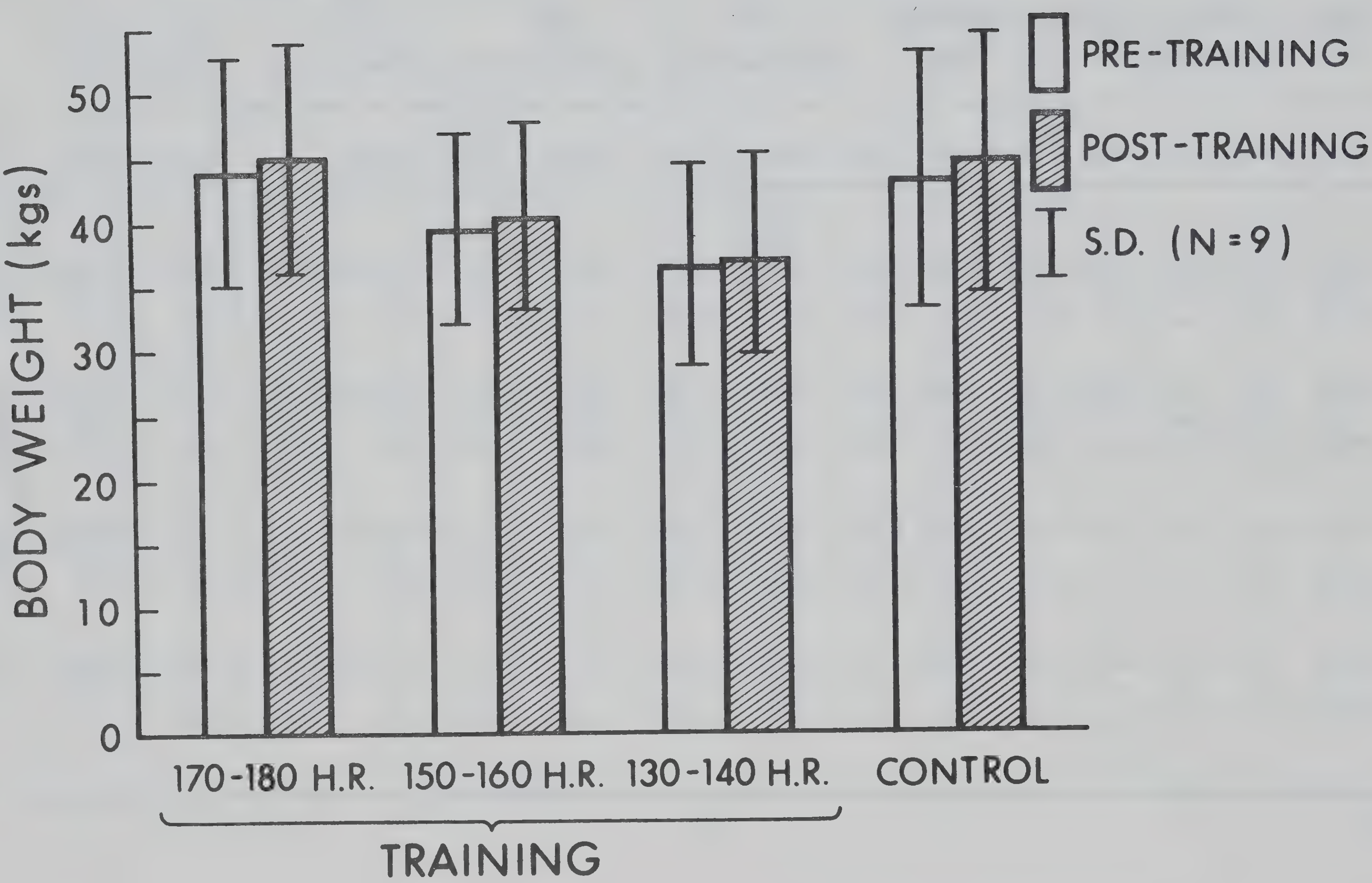

FIGURE 1 BODY WEIGHT

TABLE III

GROUP MEANS AND STANDARD DEVIATIONS FOR VARIOUS PARAMETERS AT SUBMAXIMAL WORK LOAD (450 kpm/min.) AS OBTAINED AT PRE AND POST TRAINING TESTS

Training Intensity (N=9)	Heart Rate (beats/min.)		$\dot{V}O_2$ (ml/kg/min)		$\dot{V}O_2$ (litres/min)		$\dot{V}E$ (litres/min)		LACTATE (mg%)		$\dot{V}E/\dot{V}O_2$		O_2 PULSE (ml/beat)		R.Q.	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
T1(170-180) Mean ± S.D. (N=9)	149.6 ± 19.1	133.8 ± 15.5	28.14 ± 5.4	26.32 ± 5.9	1.20 ± 0.15	1.13 ± 0.13	34.0 ± 6.9	29.7 ± 6.9	16.8 ± 5.6	12.0 ± 2.6	28.7 ± 7.5	26.7 ± 8.3	8.1 ± 1.3	8.57 ± 1.3	0.93 ± 0.11	0.98 ± 0.13
T2(150-160) Mean ± S.D. N=9)	163.2 ± 11.4	151.1 ± 14.5	29.68 ± 5.8	29.41 ± 6.2	1.14 ± 0.17	1.14 ± 0.09	31.1 ± 5.9	29.9 ± 3.9	18.6 ± 6.2	16.2 ± 4.1	27.3 ± 2.6	26.3 ± 2.9	7.0 ± 1.0	7.6 ± 0.9	0.96 ± 0.09	0.99 ± 0.12
T3(130-140) Mean ± S.D. (N=9)	168.7 ± 12.9	153.0 ± 15.6	31.48 ± 3.8	29.97 ± 3.1	1.13 ± 0.11	1.09 ± 0.10	30.9 ± 6.8	31.0 ± 4.2	21.4 ± 6.8	19.3 ± 4.5	27.3 ± 5.1	28.7 ± 5.2	6.8 ± 1.0	7.2 ± 1.1	0.95 ± 0.12	0.99 ± 0.14
T4(control) Mean ± S.D. (N=9)	154.6 ± 9.7	155.0 ± 10.4	27.48 ± 4.7	25.98 ± 3.7	1.17 ± 0.11	1.12 ± 0.13	32.7 ± 4.6	32.2 ± 3.7	24.1 ± 8.7	22.9 ± 7.4	28.2 ± 3.3	28.5 ± 4.2	7.5 ± 0.9	7.4 ± 1.1	0.96 ± 0.15	1.00 ± 0.14

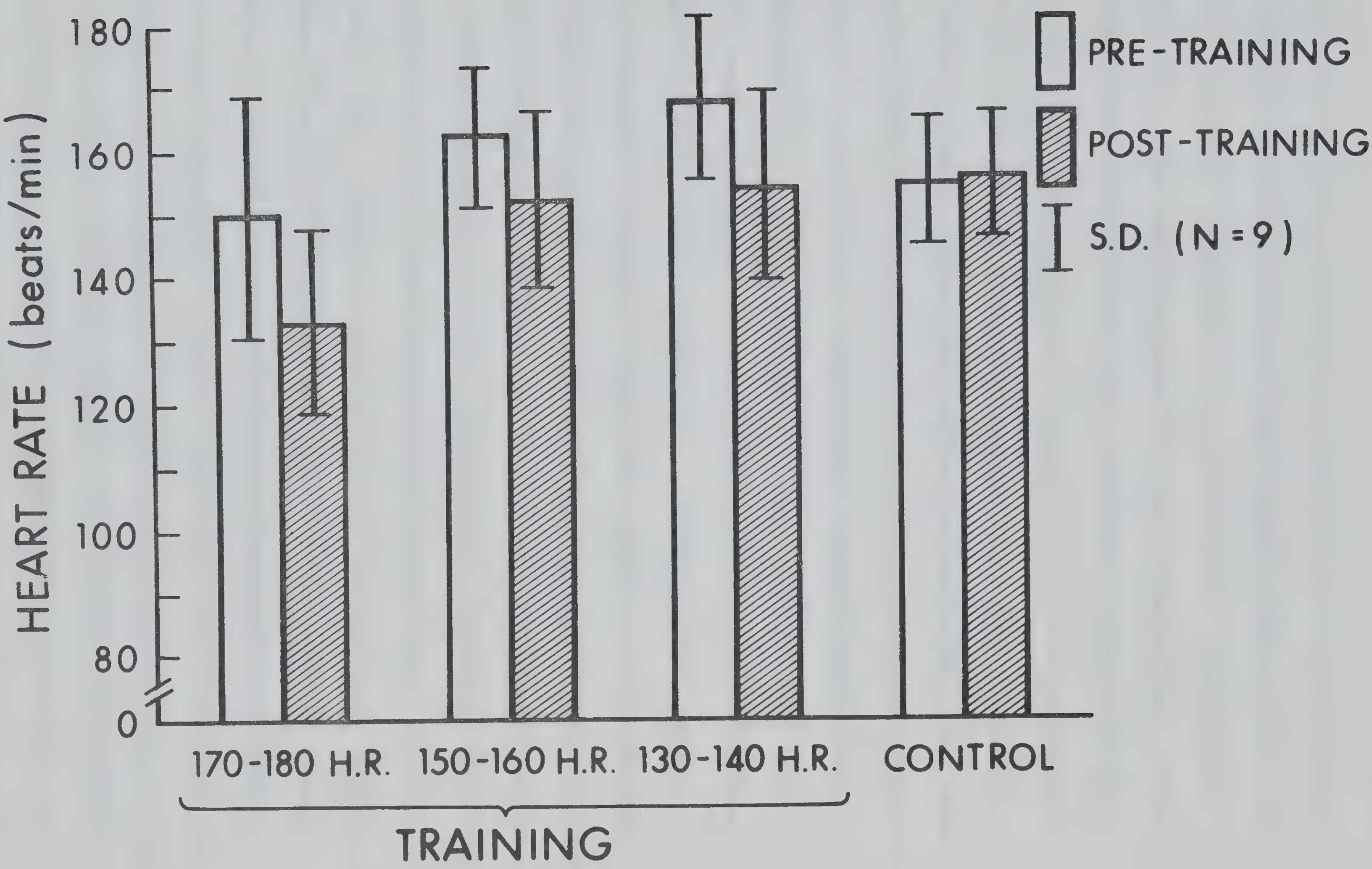

FIGURE 2 HEART RATE AT SUBMAXIMAL WORK LOAD

respectively, while the heart rate of the control group increased slightly 0.44 beat per minute (Table III). A three way ANOVA (Appendix B-1, a) showed a significant effect for time and treatment X time interaction. After plotting the means of the four treatment groups at the pre and post training test (Figure 2), it was decided to test for the simple main effects at both pre and post training values. A one way ANOVA (Appendix B-1, b) done between means at the pre training test revealed a significant ($P < .05$) F ratio, therefore a Newman-Keuls test (Appendix B-1, c) was carried out and showed that the heart rate of group T1 was significantly ($P < .05$) lower than the heart rate of group T3. Although the groups were equated on maximum oxygen consumption after the pre training test, they were not exactly similar in all physiological parameters before the training. An identical one way ANOVA (Appendix B-1, e) followed by a Newman-Keuls test (Appendix B-1, f) were carried out for the post training values; this analysis reported also a significant difference between the three training groups and the control group. However, to correct this difference between group means before the training, a Scheffe Contrast test (Appendix B-1, g) was used to compare the differences between pre and post training values for each group. This comparison between mean differences permitted to evaluate the decrease in heart rate caused by training in spite of the inequality of

the groups before training. The Scheffe Contrast test showed that the heart rates in the three training groups decreased significantly ($P < .05$) with training; there was however no significant change in the control group and also between the decreases of the three training groups.

Oxygen Consumption ($\dot{V}O_2$)

The oxygen consumption relative to body weight (ml per kg per minute) decreased very slightly in the four treatment groups (1.82, 0.27, 1.5 and 1.50 ml per kg per minute for the groups T1, T2, T3, and T4 respectively) over the six week period (Table III and Figure 3). A three way ANOVA (Appendix B-11, a) did not show any significant treatment or interaction effects. The body weight increased from 40.72kg to 41.5kg for the group's mean (Table II) over the six week program. There was also no significant change (Appendix B-III, a) in the $\dot{V}O_2$ in litres per minute (Table III, and Figure 4).

Pulmonary Ventilation ($\dot{V}E$)

The pulmonary ventilation at submaximal work load (450 kpm per min.) decreased slightly in the T1, T2 and control groups (4.3, 1.2 and 0.5 litres per min. respectively) while the group T3 increased by 0.1 litre per min. over the six week training program (Table III, Fig-

ure 5). However a three way ANOVA (Appendix B-IV) failed to show any significant treatment or interaction effects.

<u>Blood Lactate Concentration</u>

Following the six week training program the blood lactate concentration decreased in the four treatment groups (4.8, 2.4, 2.1 and 1.2mg% for the groups T1, T2, T3 and control respectively) at the submaximal work load (Table III). A three way ANOVA (Appendix B-V, a) indicated a significant time effect. After plotting the means of the four treatment groups for the pre and post training tests (Figure 6), two separate one way ANOVA to determine the simple main effects at both pre and post training tests were performed. The analysis for the four groups at the pre-training test did not show any significant differences. The one way ANOVA (Appendix B-V, b) to test for the simple main effects at the post training test revealed a significant ($P < .01$) F ratio; therefore, a Newman-Keuls test (Appendix B-V, c) was used and showed a significant ($P. < .01$) lower blood lactate concentration in the group T1 over the T3 and control groups; also, the T2 training group was significantly ($P < .05$) lower than the T3 and the control groups. However, in spite of the non-significant difference between the four groups at the

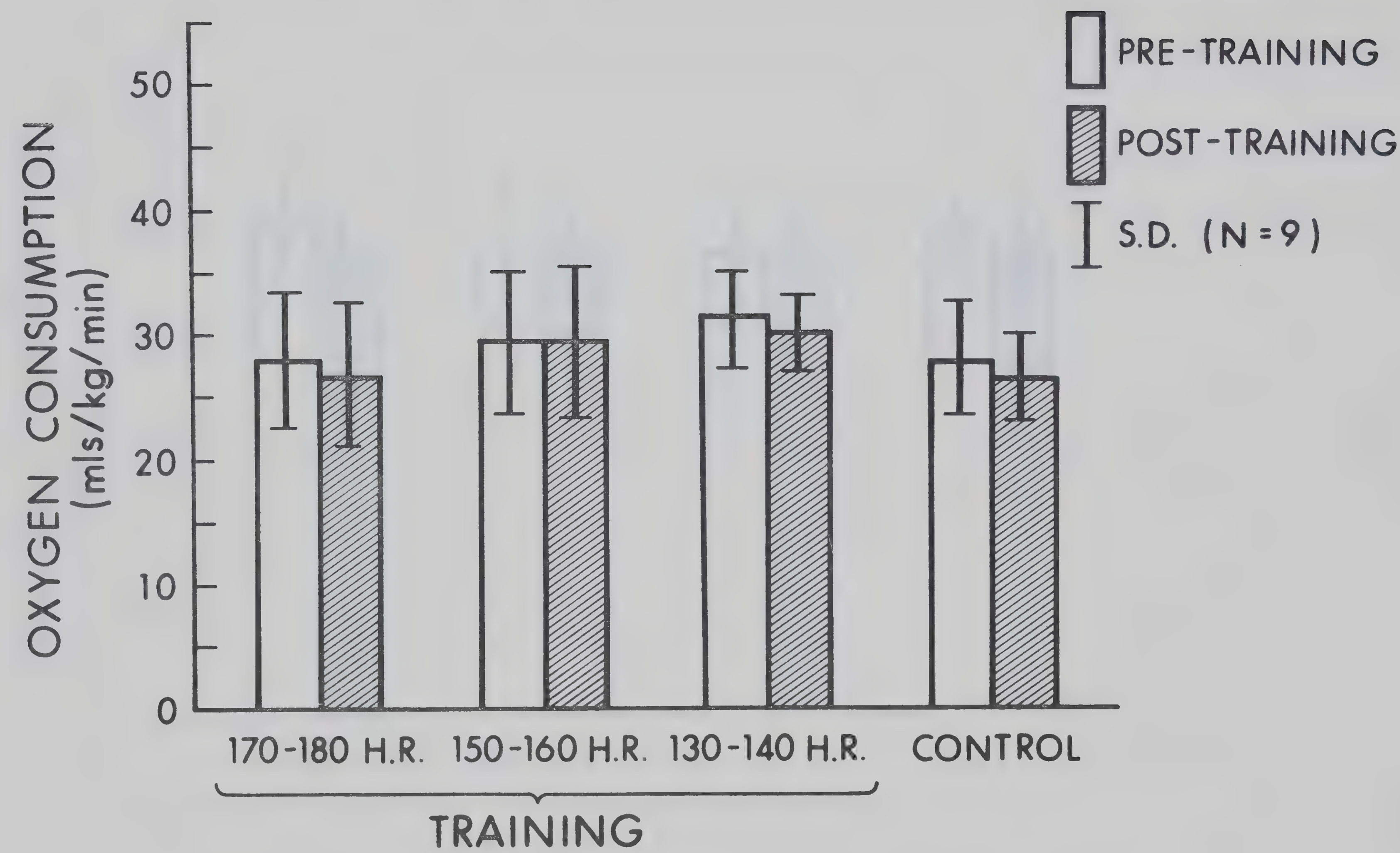

FIGURE 3 OXYGEN CONSUMPTION AT SUBMAXIMAL WORK LOAD

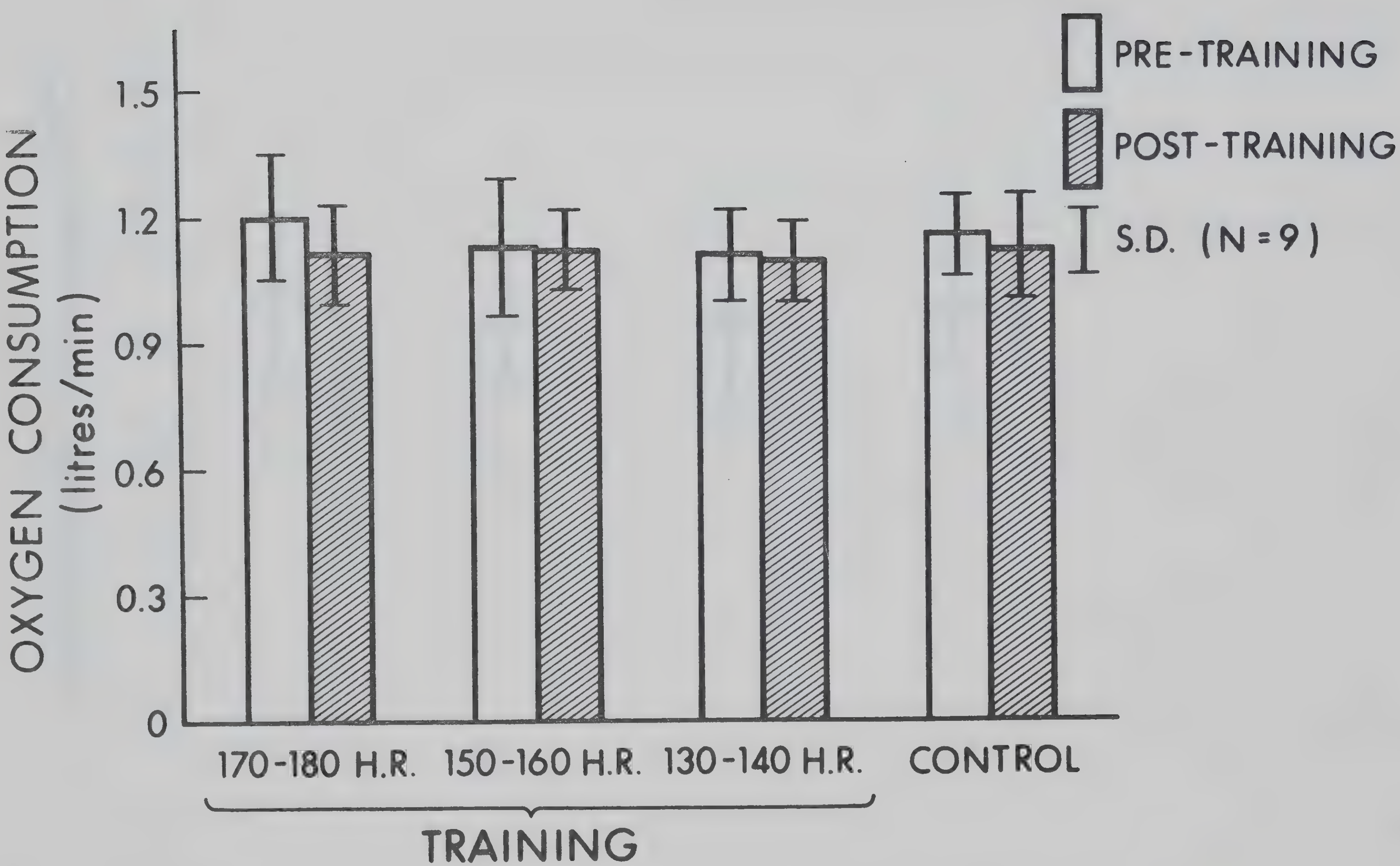

FIGURE 4 OXYGEN CONSUMPTION AT SUBMAXIMAL WORK LOAD

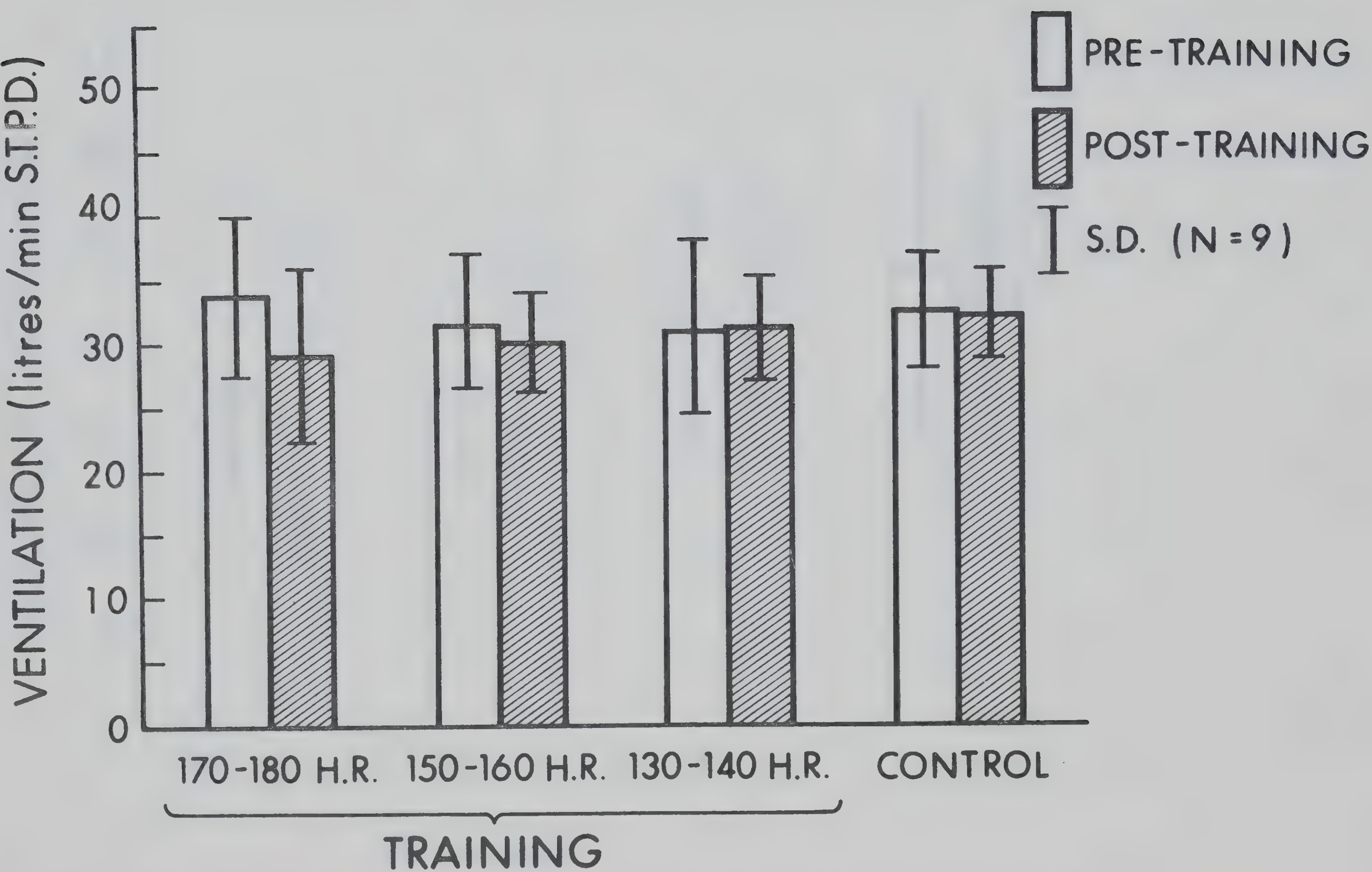

FIGURE 5 PULMONARY VENTILATION AT SUBMAXIMAL WORK LOAD

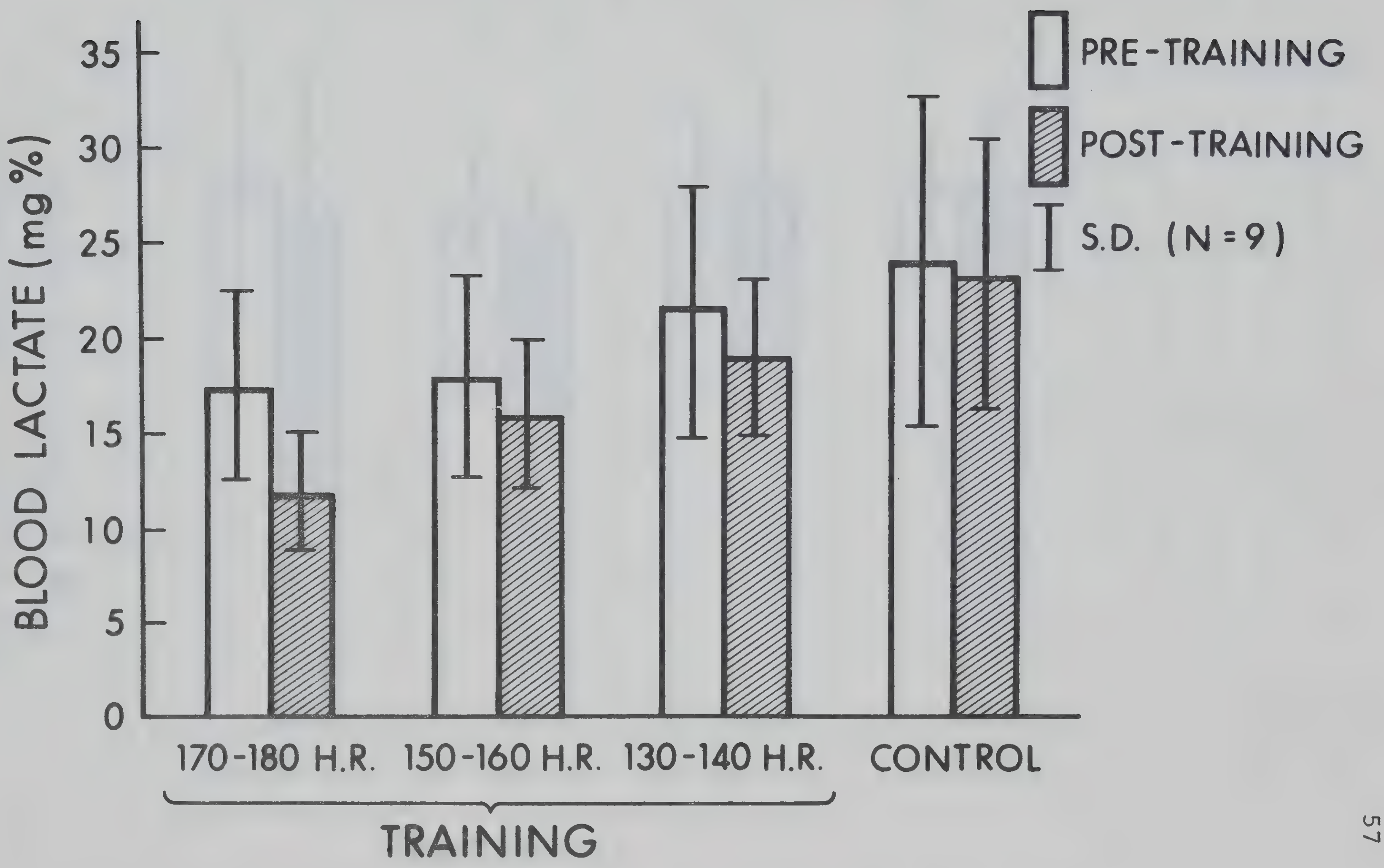

FIGURE 6 BLOOD LACTATE CONCENTRATION AT SUBMAXIMAL WORK LOAD

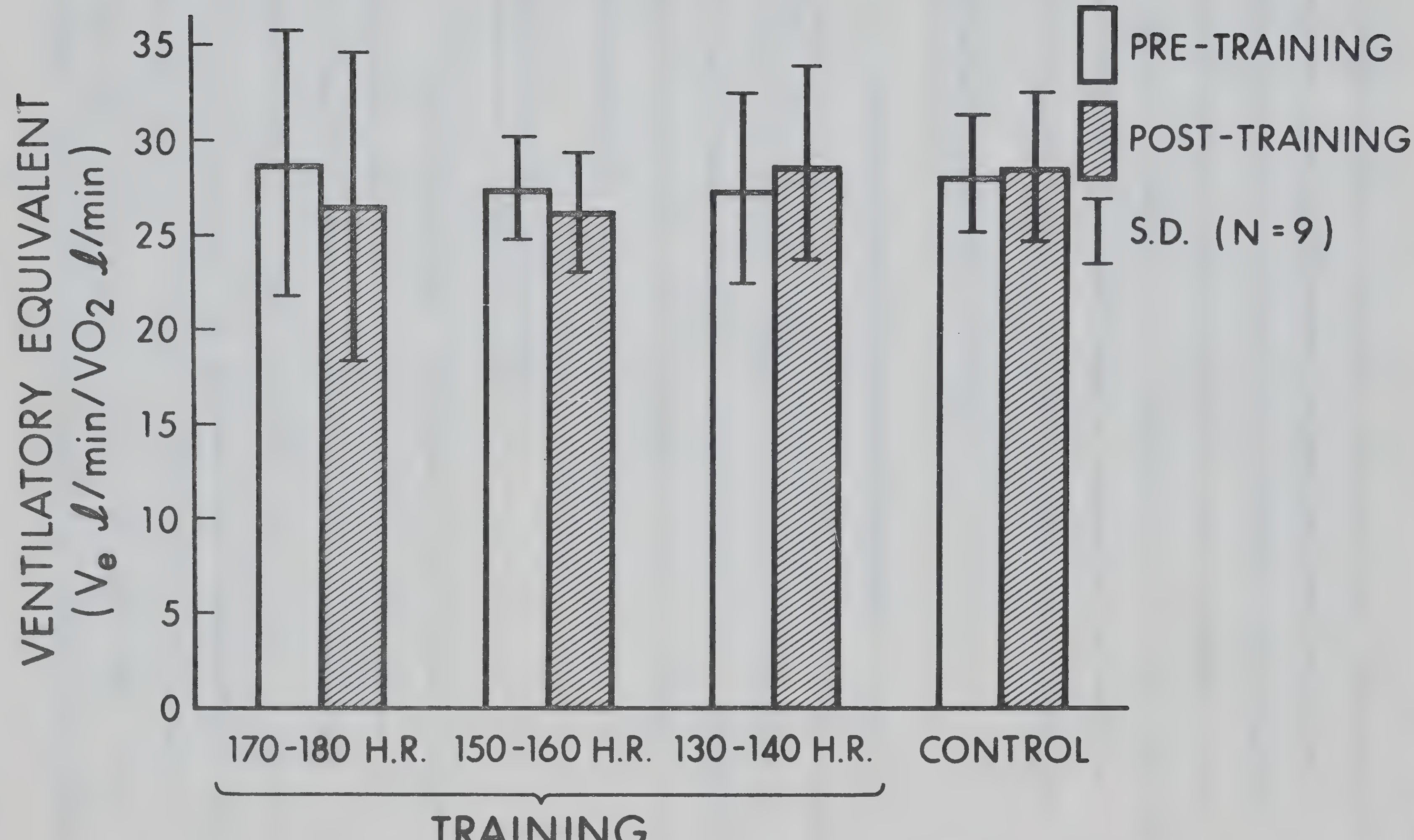

FIGURE 7 VENTILATORY EQUIVALENT AT SUBMAXIMAL WORK LOAD

pre-training test, a Scheffe Contrast test (Appendix B-V, d) between mean differences at pre and post training values was used to evaluate the decreases with training in blood lactate concentration for each treatment group. The analysis resulted in a significant ($P < .05$) decrease after training in blood lactate concentration only in the T1 training group. No other change was significant.

Ventilatory Equivalent ($\dot{V}E/\dot{V}O_2$)

The ventilatory equivalent decreased in the T1, T2 training groups (2.0 and 1.0 respectively) and increased in the T3 and control groups (1.4 and 0.3 respectively) over the six week training program (Table III, Figure 7). However a three way ANOVA (Appendix B-VI, a) failed to show any treatment or interaction effects.

Oxygen Pulse ($\dot{V}O_2$/heart beat)

The oxygen pulse increased in the three training groups after the training period (Table III, Figure 8), and a three way ANOVA (Appendix B-VII, a) suggested treatment effect. After plotting the results, a one way ANOVA (Appendix B-VII, b) followed by a Newman-Keuls test (Appendix B-VII, c) revealed a significant difference between the four groups at the pre-training test. The treatment effect found in the three way ANOVA was probably

due to the differences between groups before the training. However, a Scheffe Contrast test (Appendix B-VII, d) used to evaluate the increases with training in each group did not show any significant improvement following training.

RESULTS AT MAXIMAL WORK LOAD

The pre and post training data for the various physiological parameters are reported in Table IV (mean and S.D. for each group). The statistical analysis for each parameter is summarized in the Appendix C.

Maximal Work Load (kpm per minute)

Following the six week training program the work load necessary to reach the maximum oxygen consumption increased in the three training groups while it remained unchanged in the control group (Figure 9). These increases were 250, 216.7 and 183.3 kpm per minute in the T1, T2 and T3 groups respectively (Table IV). A three way ANOVA (Appendix C-1, a) showed a significant treatment effect for time and time X treatment interaction. After plotting the means of the four treatment groups for the pre and post training tests, two separate one way ANOVA were employed to determine the simple main effects at both the pre and post training tests. The one way ANOVA (Appendix C-1, B) for the four group means at the pre-training test reported

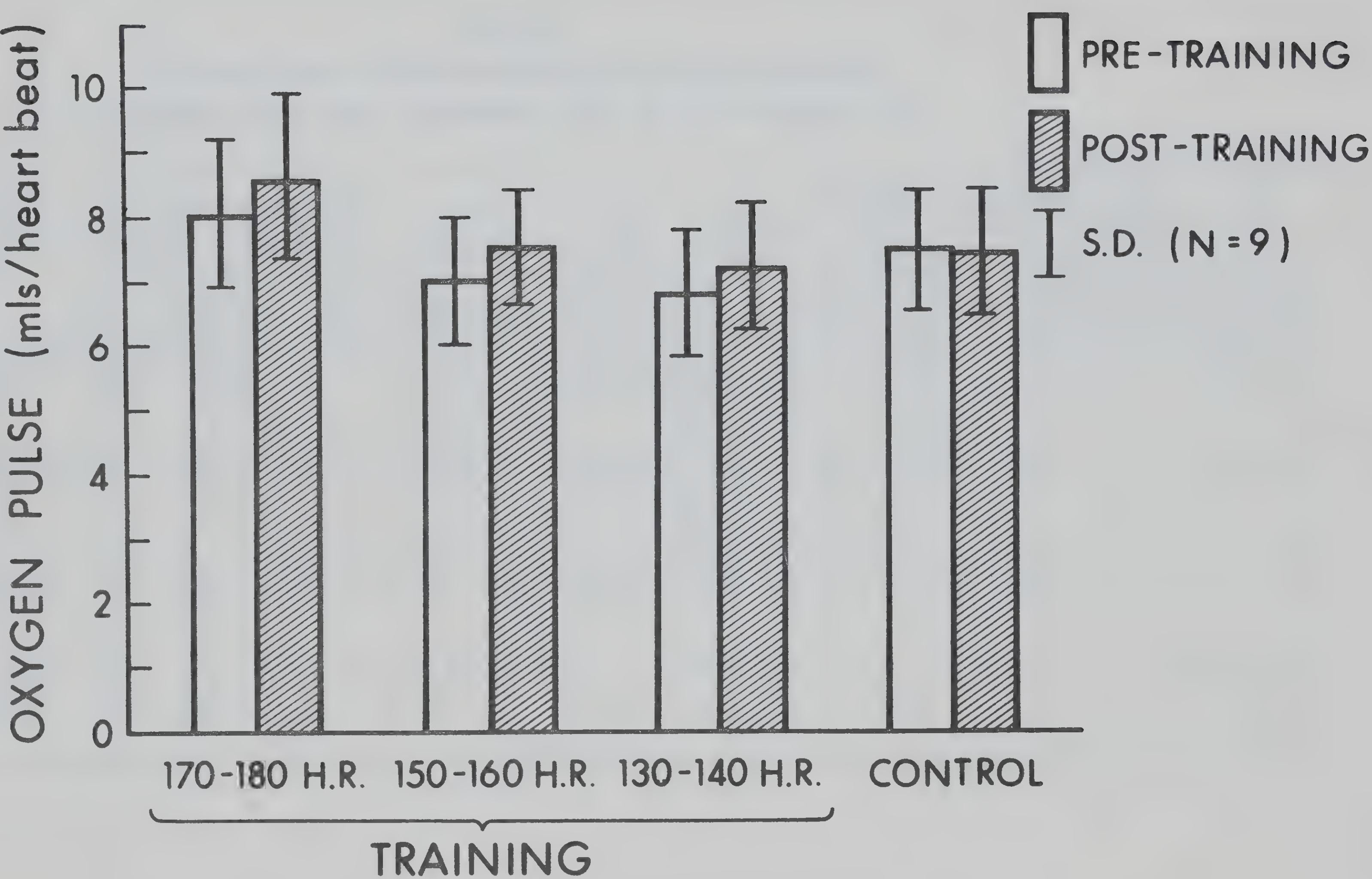

FIGURE 8 OXYGEN PULSE AT SUBMAXIMAL WORK LOAD

TABLE IV

GROUP MEANS AND STANDARD DEVIATIONS FOR VARIOUS PARAMETERS

AT MAXIMAL WORK LOADS AS OBTAINED AT PRE AND POST TRAINING TESTS

Training Intensity (N=9)	WORK LOAD (kpm/min)		HEART RATE (beats/min		$\dot{V}O_2$ (ml/kg/min)		$\dot{V}O_2$ (litres/ min)		$\dot{V}E$ (litres/ min)		LACTATE (mg%)		$\dot{V}E/\dot{V}O_2$		O_2 PULSE (ml/beat)		R.Q.	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
T1(170-180) Mean ± S.D. (N=9)	1000.0 ± 129.9	1250.0 ± 167.7	193.4 ± 5.2	194.3 ± 5.1	46.68 ± 7.5	51.75 ± 6.0	2.03 ± 0.43	2.29 ± 0.45	66.0 ± 14.4	70.7 ± 12.7	71.7 ± 11.5	86.8 ± 13.1	32.7 ± 4.2	31.2 ± 3.8	10.4 ± 2.1	11.8 ± 2.2	1.11 ± 0.20	1.13 ± 0.22
T2(150-160) Mean ± S.D. (N=9)	916.7 ± 117.3	1133.3 ± 152.1	197.9 ± 7.9	196.3 ± 7.2	47.44 ± 7.8	48.00 ± 6.0	1.82 ± 0.38	1.90 ± 0.36	58.5 ± 11.8	61.7 ± 11.3	83.6 ± 17.3	94.6 ± 21.9	32.3 ± 4.1	32.8 ± 4.3	9.3 ± 2.2	9.7 ± 2.1	1.13 ± 0.19	1.17 ± 0.21
T3(130-140) Mean ± S.D. (N=9)	833.3 ± 132.3	1016.7 ± 125.0	195.2 ± 3.8	194.3 ± 4.2	46.56 ± 6.4	48.24 ± 3.6	1.67 ± 0.22	1.77 ± 0.20	55.5 ± 7.6	58.4 ± 6.6	84.9 ± 23.1	91.7 ± 16.5	33.5 ± 4.6	33.2 ± 2.9	8.7 ± 1.0	9.1 ± 1.0	1.08 ± 0.15	1.10 ± 0.17
T4(control) Mean ± S.D. (N=9)	966.7 + 109.0	966.7 + 109.0	194.1 ± 8.9	195.3 ± 5.9	45.66 ± 3.5	44.19 ± 3.1	1.97 ± 0.27	1.94 ± 0.25	63.1 ± 10.4	65.4 ± 12.2	83.3 ± 18.6	87.0 ± 21.0	32.1 ± 4.1	33.7 ± 4.2	10.4 ± 1.5	9.9 ± 1.2	1.13 ± 0.20	1.15 ± 0.19

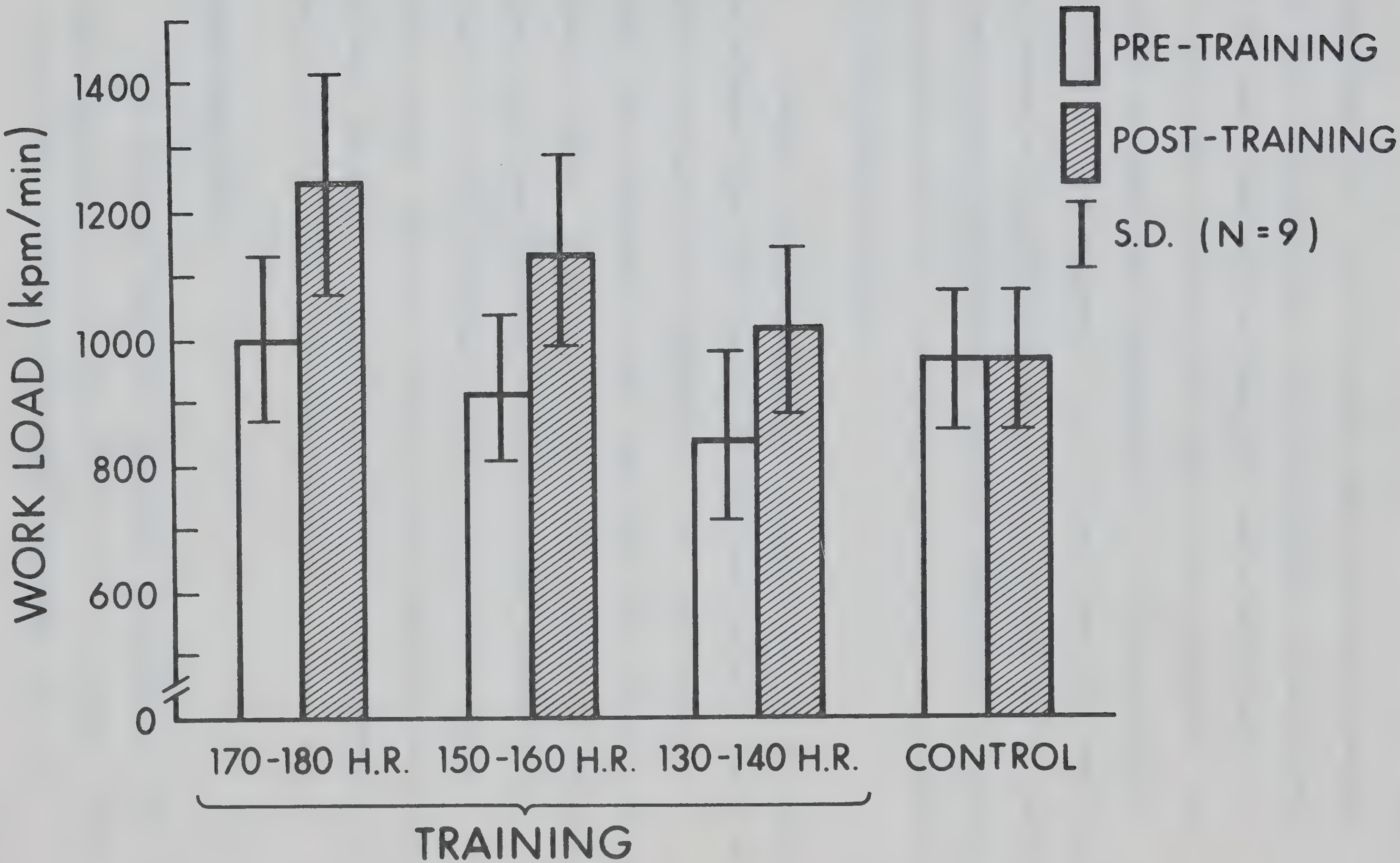

FIGURE 9 WORK LOADS AT MAXIMUM OXYGEN CONSUMPTION

a significant ($P < .05$) F ratio, and therefore a Newman-Keuls test (Appendix C-1, c)) was carried out and showed that the work load of the group T1 was significantly ($P < .05$) higher than the work load of the group T3. An identical one way ANOVA (Appendix C-1, e) followed by a Newman-Keuls test (Appendix C-1, f) were used for the four group means at the post training test. These tests led to the conclusion that the work loads of the group T1 and T2 were significantly ($P < .01$) higher than the work loads of the T3 and control groups.

However, to compensate for the inequality of work loads between the four groups at the pre training test, a Scheffe Contrast test (Appendix C-1, g) was used to evaluate the increase of work load with the training for each treatment group. This comparison between mean differences (before and after training for each group) showed a significant ($P < .01$) increase of work load in the three training groups while the control group remained unchanged. There was, however, no significant difference between the increases of the three training groups.

Maximum Heart Rate

The maximum heart rate remained unchanged in the four treatment groups over the six week training program (Table IV, Figure 10). A three way ANOVA (Appendix C-11, a)

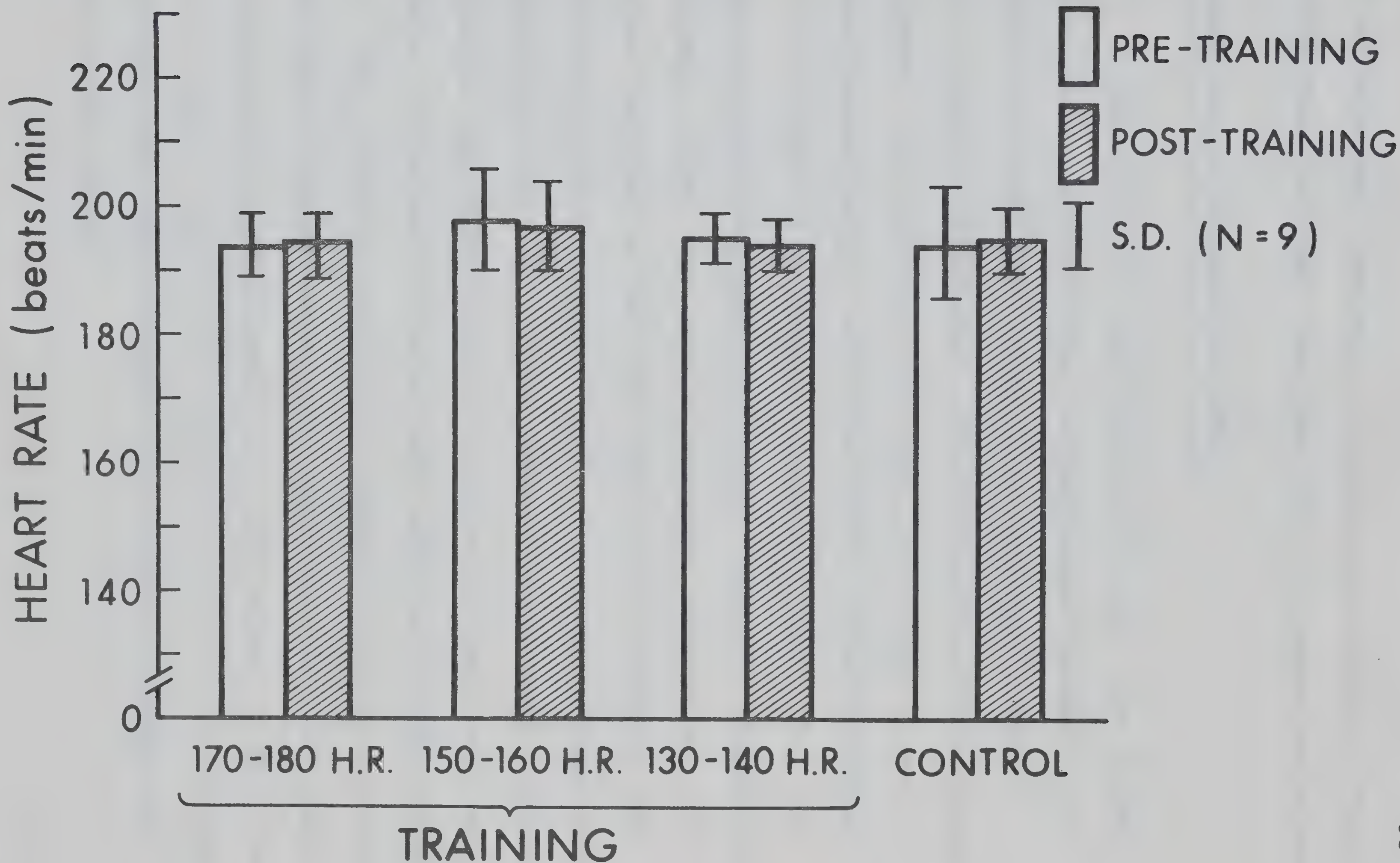

FIGURE 10 HEART RATE AT MAXIMAL WORK LOAD

did not show any treatment or interaction effects. The groups' mean for heart rate was 195 ± 5.5 beats per minute.

Maximum Oxygen Consumption ($M\dot{V}O_2$)

After the six week training program, the maximum oxygen consumption relative to body weight showed a substantial increase only in the high training group T1 (5.6 ml per kg per minute). The T2 and T3 training groups increased very slightly (0.56 and 1.68 ml per kg per minute respectively), while the control group decreased by 1.97 ml per kg per minute (Table IV, Figure II). A three way ANOVA (Appendix C-III, a) revealed a significant treatment effect, and time X treatment interaction. It was not required to test for simple main effects at the pre-training test, because the four treatment groups were equated on their $M\dot{V}O_2$ values before the training. A one way ANOVA (Appendix C-III, b) to test for the simple main effects at the post-training test indicated a significant ($P < .05$) F ratio; therefore, a comparison of the treatment means with a Newman-Keuls test (Appendix C-III, c) showed T1 group to be significantly ($P < .05$) higher in $M\dot{V}O_2$ than the two other training and control groups. No significant difference was found between the T2 and T3 training and the control groups.

The $\dot{M}VO_2$ in litres per minute increased in the three training groups (0.27, 0.08 and 0.10 litres per minute for the T1, T2 and T3 groups respectively) while the $\dot{M}VO_2$ in the control group decreased slightly (0.03 litre per minute) over the six week period (Table IV, Figure 12). An identical three way ANOVA (Appendix C-IV, a) and a one way ANOVA (Appendix C-IV, b) followed by a Newman-Keuls test (Appendix C-IV, c) using the post training values showed the T1 group to be significantly ($P < .01$) higher in $\dot{M}VO_2$ than the T3 group and also, significantly ($P < .05$) higher than the T2 and control groups.

Maximal Pulmonary Ventilation ($M\dot{V}E$)

The four treatment groups increased slightly in maximum pulmonary ventilation (4.7, 3.2, 2.9 and 2.3 litres per minute for the group T1, T2, T3 and control groups respectively) over the six weeks of training (Table IV, Figure 13). However, the three way ANOVA (Appendix C-V, a) failed to report any significant treatment or interaction effects.

Maximum Blood Lactate Concentration

The maximum blood lactate concentration (mg per 100 mls of blood) increased in the four treatment groups (15.1, 11.0, 6.8 and 3.7mg% for the T1, T2, T3 and control groups

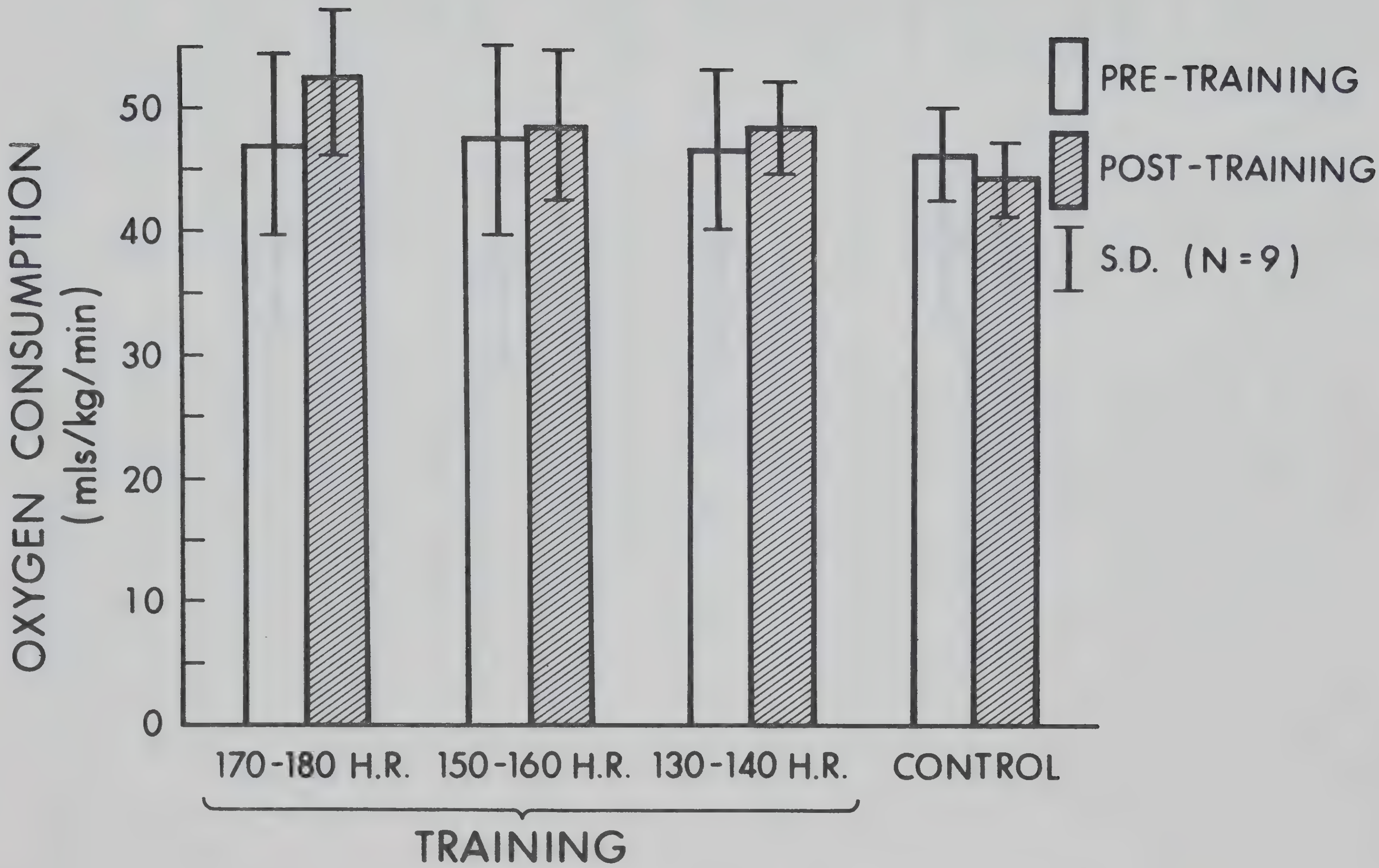

FIGURE 11 MAXIMUM OXYGEN CONSUMPTION

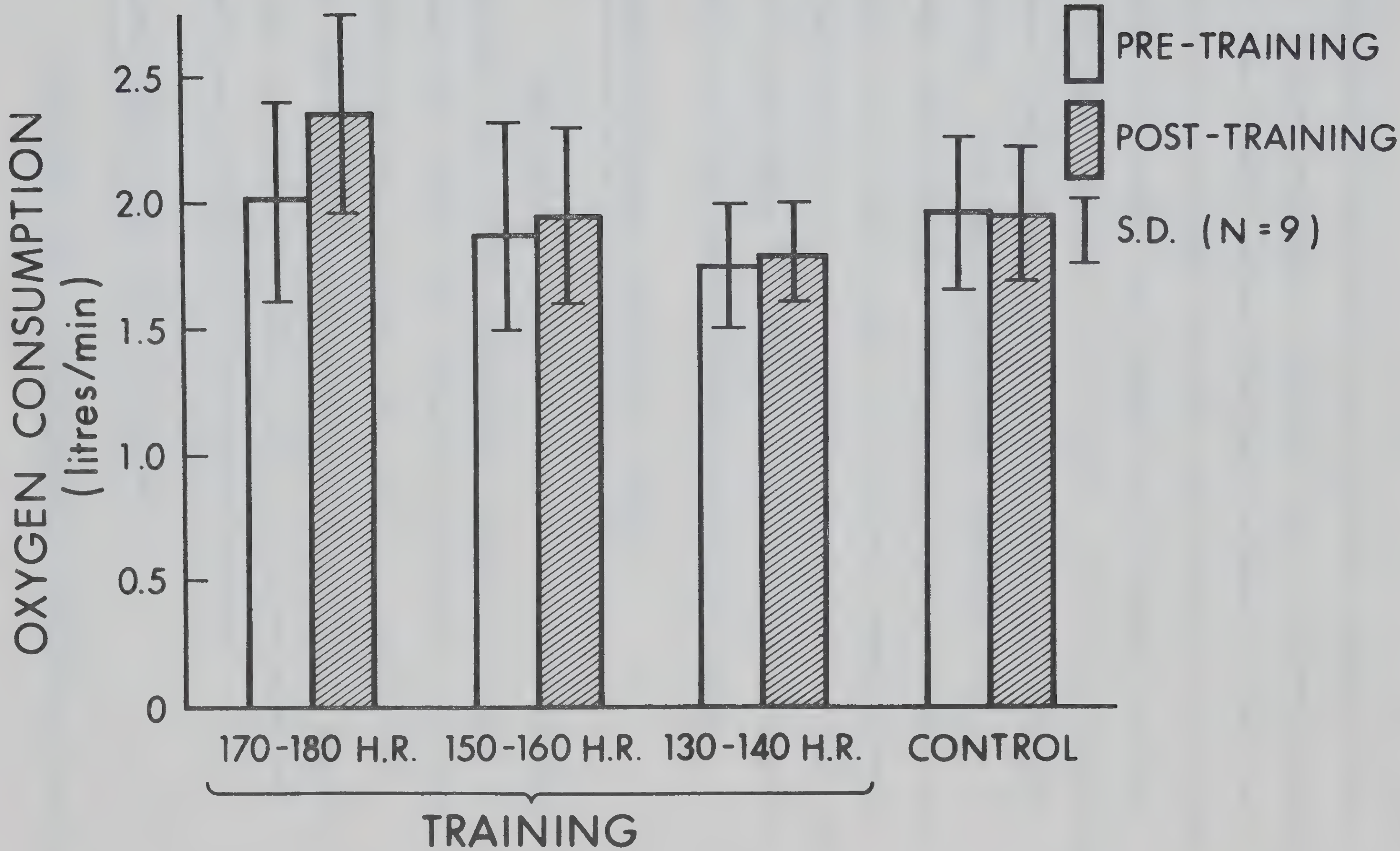

FIGURE 12 MAXIMUM OXYGEN CONSUMPTION

respectively) after the six week training program (Table IV). A three way ANOVA (Appendix C-VI, a) showed a significant time effect. After plotting the means of the four groups at pre and post training tests (Figure 14), it was decided to evaluate the increase with training in blood lactate concentration for each group. Due to the inequality between groups at the initial blood lactate level before training, a Scheffe Contrast test (Appendix C-VI, b) between mean differences (before and after training) was carried out for each group. The analysis demonstrated a significant ($P < .05$) increase in blood lactate only for the T1 group after the training; no other difference was found in the two other training and control groups.

Maximum Ventilatory Equivalent ($\dot{V}E/\dot{V}O_2$)

There were slight decreases in maximum ventilatory equivalent for the T1, T3 training groups (1.5 and 0.3 respectively) while this parameter increased in the T2 training and control groups (0.5 and 0.6 respectively) over the six week period (Table IV, Figure 15). However a three way ANOVA (Appendix C-VII, a) did not show any significant treatment or interaction effects.

Maximum Oxygen Pulse ($\dot{V}O_2$/Heart Beat)

Following the six week training program the maximum

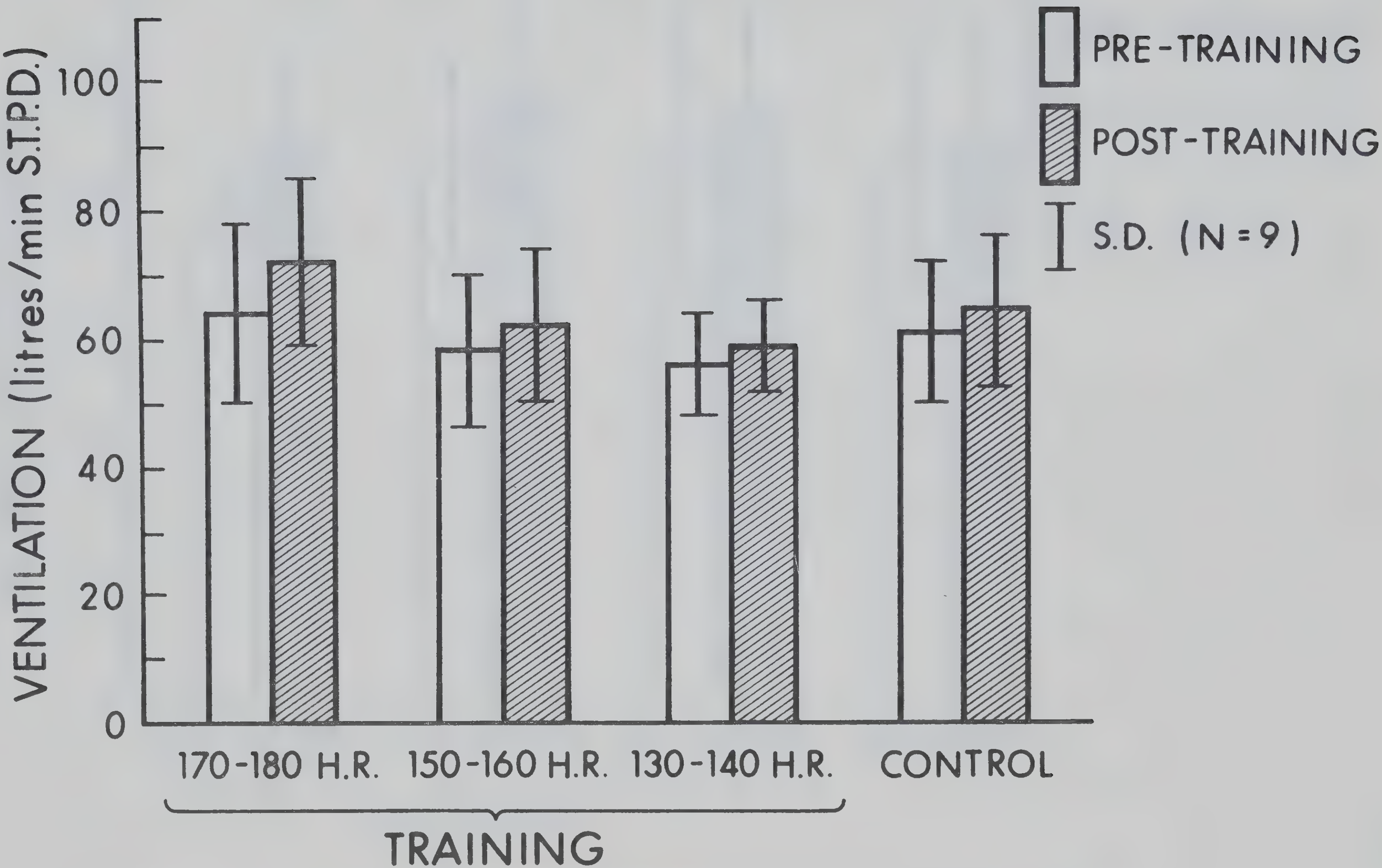

FIGURE 13 PULMONARY VENTILATION AT MAXIMAL WORK LOAD

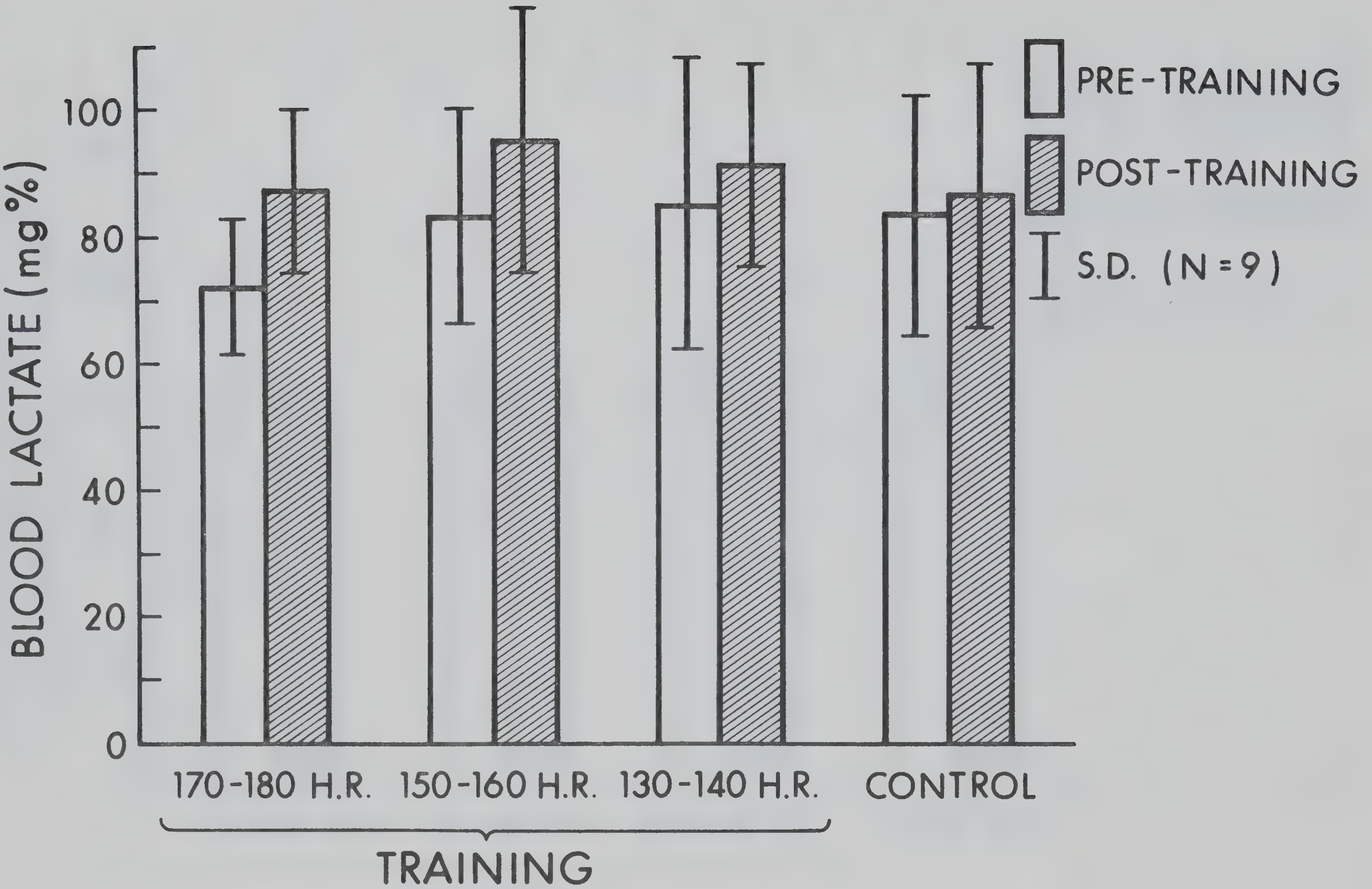

FIGURE 14 BLOOD LACTATE CONCENTRATION AT MAXIMAL WORK LOAD

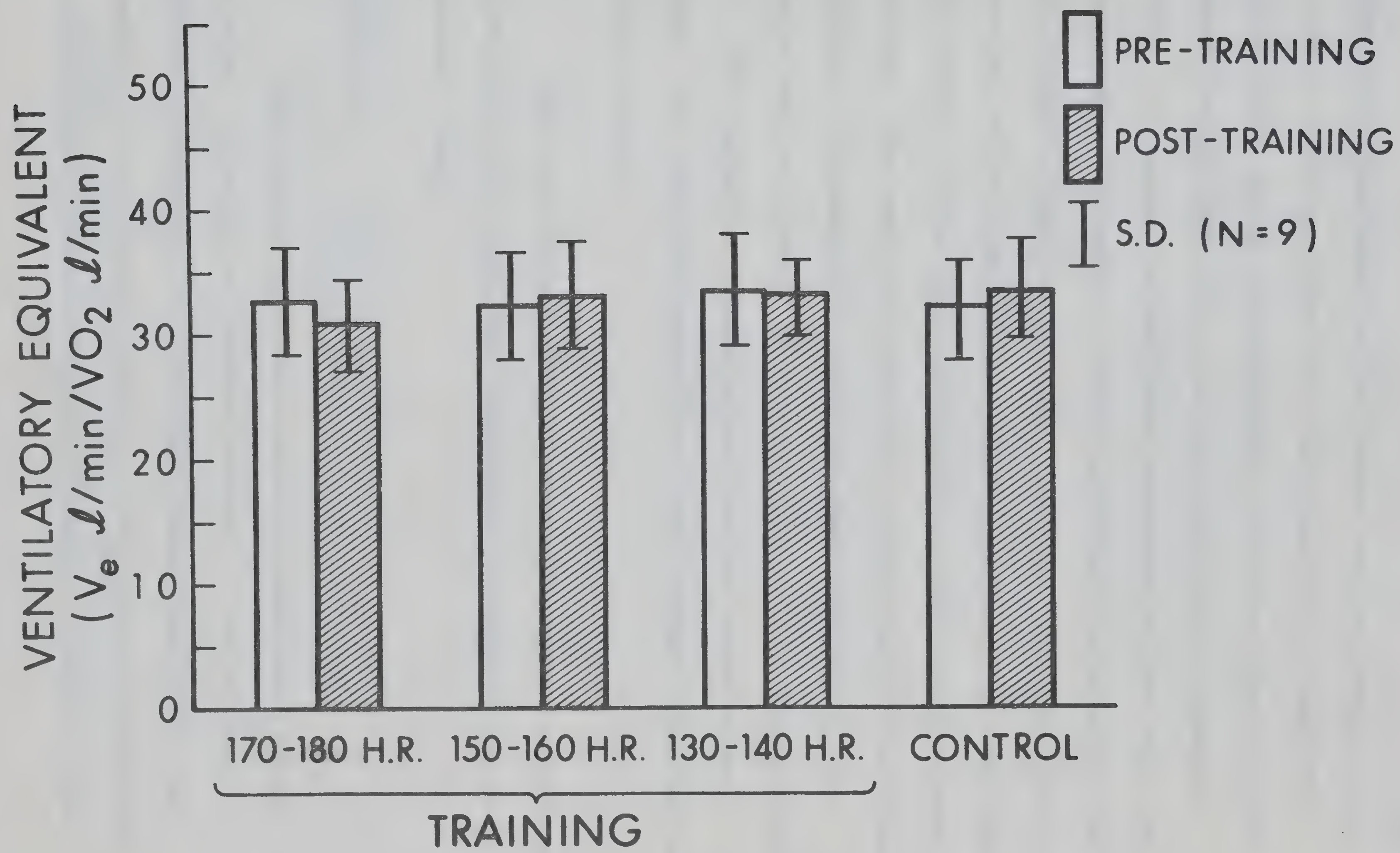

FIGURE 15 VENTILATORY EQUIVALENT AT MAXIMAL WORK LOAD

oxygen pulse increased in the three training groups (1.4, 1.1 and 0.4 mls per beat for the groups T1, T2 and T3 respectively) while it decreased (.05 ml per beat) in the control group (Table IV). A three way ANOVA (Appendix C-VIII, a) showed a significant treatment effect and time X treatment interaction. After plotting the means of the four groups at the pre and post training tests (Figure 16), a one way ANOVA (Appendix C-VIII, b) to test for the simple main effects of the four treatments at post-training test was done. The analysis revealed a significant F ratio and therefore a Newman-Keuls test (Appendix C-VIII, c) was carried out and showed T1 training group to be significantly ($P < .05$) higher in oxygen pulse than the three other groups. No other difference was found between training and control groups.

The significant changes with training at submaximal and maximal work loads are summarized in Table V for each treatment group.

DISCUSSION

Adaptation to physical activity manifests itself in two ways: firstly, by greater economy of the trained organism in response to a standard submaximal work load; secondly, by the greater ability of the trained individual to perform more intense work for a longer period of time,

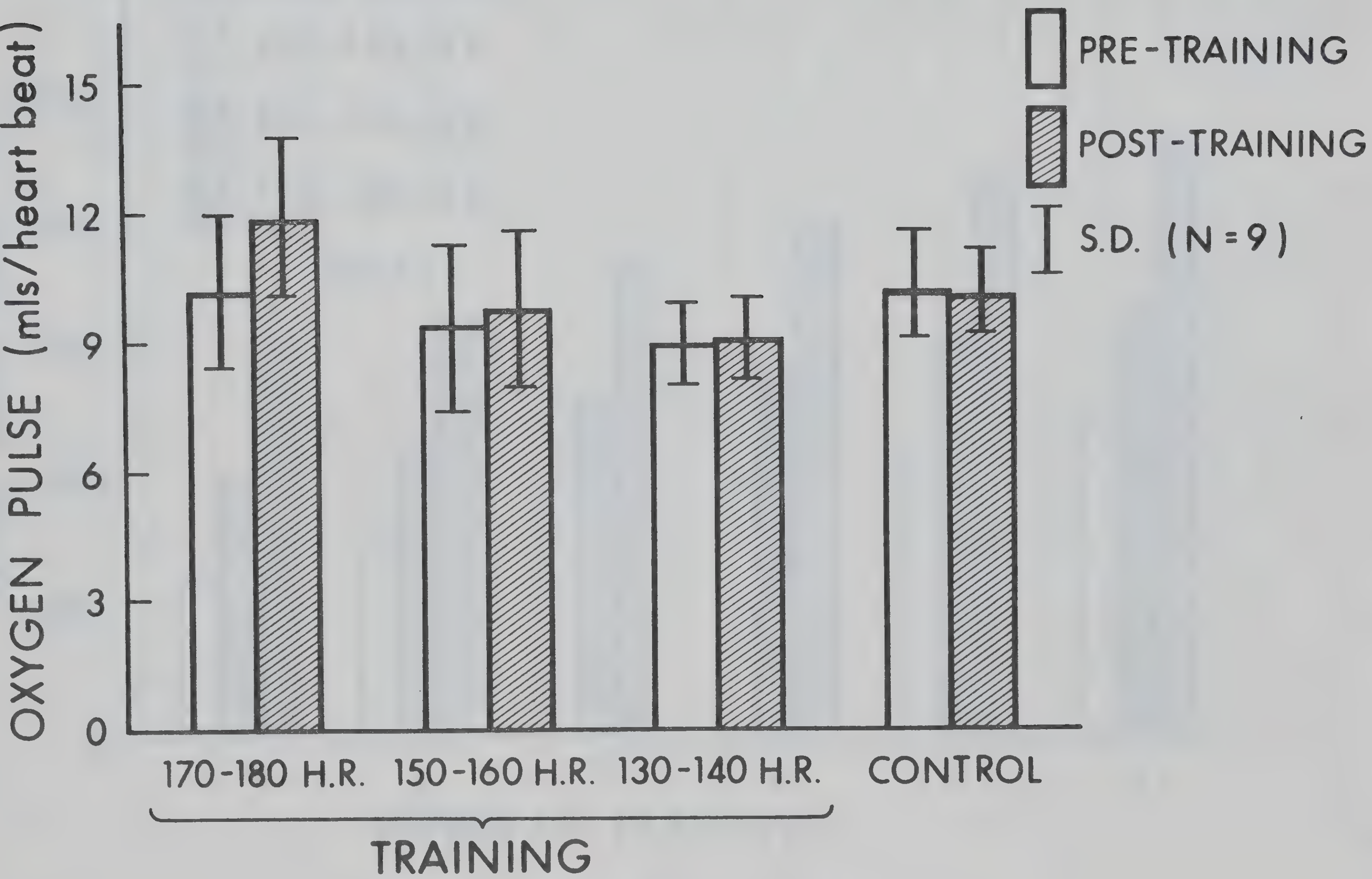

FIGURE 16 OXYGEN PULSE AT MAXIMAL WORK LOAD

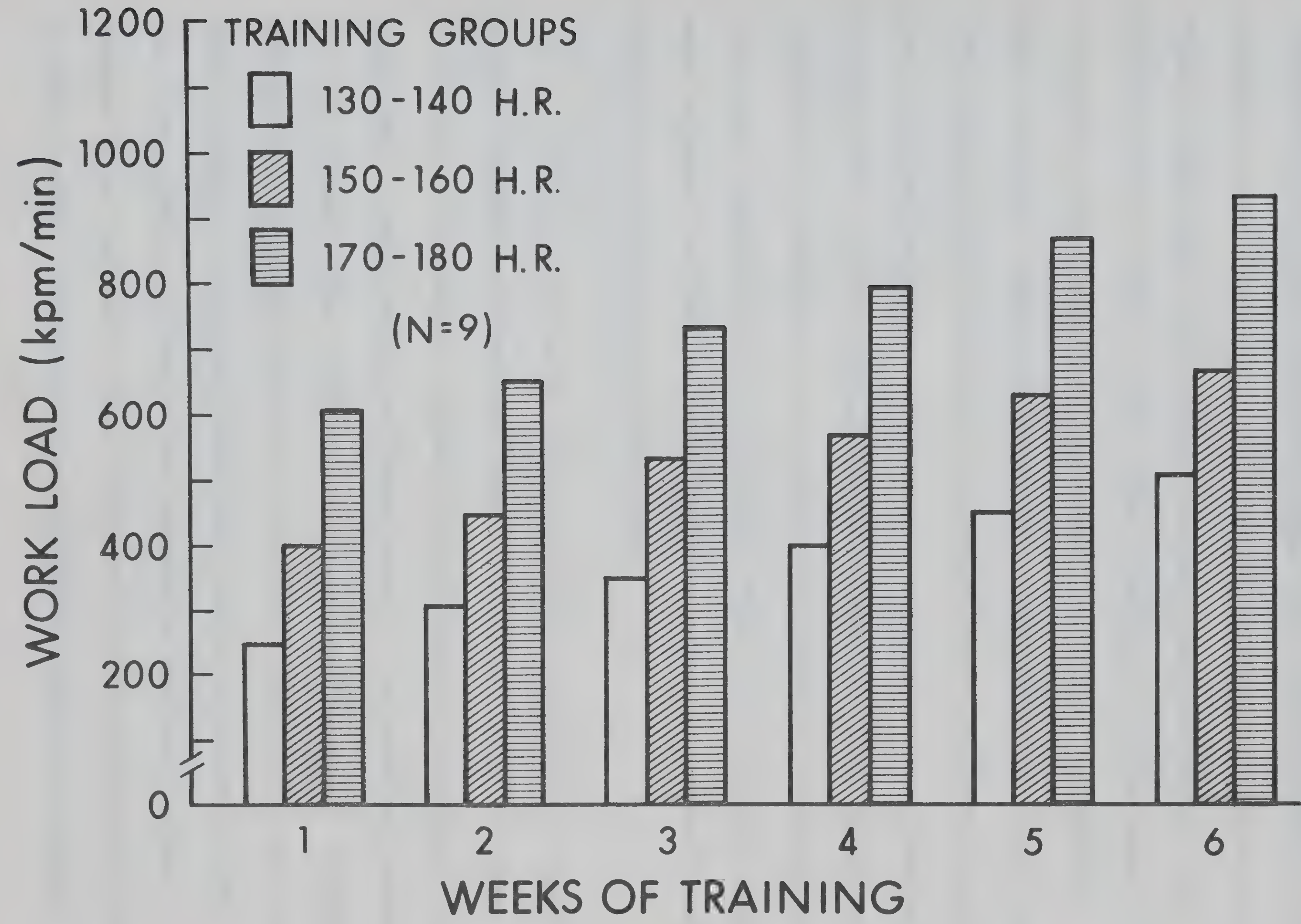

FIGURE 17 TRAINING WORK LOADS

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since he has an increased functional cardiorespiratory capacity. In most of the previous investigations on the effects of physical training upon the oxygen transporting system in man, the subjects have consisted exclusively of adult individuals (5, 16,21, 24, 29, 31, 38, 40,45, 53, 54, 66, 88, 97, 103, 120). The training factors most frequently mentioned are exercise intensity, duration and frequency. Many studies (37, 42, 67,82, 102,103, 105, 120) dealing with exercise intensity have indicated that the training stimulus is directly related to the intensity of exercise. The training program used in this study was designed to determine the relative effects of three different training intensities in children, when the training groups were equated on the initial fitness level, frequency and duration of the training sessions.

It is well known that training can cause a decrease of the submaximal exercise heart rate and several types of tests of "Physical Fitness" are based on counting the exercise or post-exercise heart rate. The work of Astrand (9, 10) showed that there was a close correlation between the maximum oxygen uptake of a subject and his or her heart rate response to graded exercise, and this correlation has been used as a basis for assessing maximum oxygen uptake from the heart rate recorded during submaximal work. In this study, following the six week training program, the

TABLE V

SUMMARY TABLE OF THE SIGNIFICANT CHANGES WITH TRAINING FOR THE VARIOUS PARAMETERS AT SUBMAXIMAL AND MAXIMAL WORK LOADS

PARAMETERS	TREATMENT GROUPS T1 (170-180)	T2 (150-160)	T3 (130-140)	T4 (Control)
SUBMAXIMAL WORK LOAD (450 kpm/min.)				
Heart Rate (beats/min.)	$*\vee$	$*\vee$	$*\vee$	
$\dot{V}O_2$ (ml/kg/min.)				
$\dot{V}O_2$ (litres/min.)				
$\dot{V}E$ (litres/min.)				
Lactate (mg%)	$*\vee$			
$\dot{V}E/\dot{V}O_2$				
O_2 Pulse (ml/beat)				
MAXIMAL WORK LOAD				
Work Load (kpm/min.)	$**\wedge$	$**\wedge$	$**\wedge$	
Heart Rate (beats/min.)				
$M\dot{V}O_2$ (ml/kg/min.)	$*\wedge$			
$M\dot{V}O_2$ (litres/min.)	$*\wedge$			
$M\dot{V}E$ (litres/min.)				
Lactate (mg%)	$*\wedge$			
$\dot{V}E/\dot{V}O_2$				
O_2 Pulse (ml/beat)	$*\wedge$			

** significant at α .01

* significant at α .05

$\wedge$ increase; $\vee$ decrease

heart rate at the given submaximal work load decreased significantly ($P < .05$) in the three training groups (15.8, 13.7 and 12.1 beats per minute for the T1, T2 and T3 groups respectively) but remained unchanged in the control group (Figure 2). The 11%, 9% and 8% decreases in heart rate for the T1, T2 and T3 groups respectively are in line with the results reported previously (5, 9, 33, 37, 40, 54, 86, 88, 97, 99). The largest decrease of heart rate was 28 beats per minute for a subject in the T1 group.

The factors governing the effect of training on the heart rate are multiple. The increase of the heart rate during work is considered to be partly due to a reflex response, in which the afferent stimuli come from the working muscles (10). As a general concept, Karvonen (67) suggested that the impulse drive from the muscles becomes particularly intense when the conditions in the muscles become anaerobic. Thus, the training improves the oxygen transport system to the working muscles and consequently, anaerobic conditions are not as easily produced in a trained muscle as in an untrained one. However, this concept was discussed by many physiologists such as Astrand (13), Ekblom et al. (40, 42) Hartley et al. (54), Shephard et al. (105, 109) and Saltin et al. (96, 97, 98, 99), and they suggested that this decrease in heart rate at submaximal work load following training was due to either an increase in stroke

volume and/or an increase in arteriovenous oxygen difference or both effects combined. The work of Saltin *et al*. (96, 97), Hartley *et al*. (54) and Bevegard (15) have shown that the cardiac output does not change at submaximal work load after training and concluded that the stroke volume increases to compensate for a lower heart rate. On the other hand, Andrew *et al*. (55), Douglas *et al*. (37) and Tabakin *et al*. (114) have reported a decrease in cardiac output at submaximal work load following training due to a significant decrease in heart rate while the stroke volume remain unchanged. Supporting this concept, Ekblom *et al*. (40) attributed this decrease in heart rate mainly to an increased arteriovenous oxygen difference rather than an increased stroke volume. The improvement in the arteriovenous oxygen difference might be due to a more complete extraction of the oxygenated blood in the working muscles, and/or a more effective regulation of the cardiac output, that means more blood in the working muscles and less blood in the inactive parts of the body. However, these investigators (37, 40, 55, 114) who reported a lower cardiac output at submaximal work load after training have partly attributed their observations to a redistribution of blood flow from other body tissues to the exercising muscles. Precisely, they suggested that, after training, the perfusion of the exercising muscles was favored by a

more pronounced restriction of splanchnic and renal blood flow. But in fact the opposite effect was demonstrated by Rowell _et al_. (94) who found that the decrease in the splanchnic and renal blood flow was less pronounced in trained than in untrained persons during a given submaximal exercise. Furthermore, recent studies performed by Clausen _et al_. (20, 21) and Grimby and Saltin (50) with the ^{133}Xenon-clearance method have demonstrated that muscle blood flow is reduced when measuring at identical submaximal work loads before and after training. According to these findings, it seems that the increase of the arteriovenous oxygen difference at the submaximal work load following training is mainly caused by a more complete extraction of the oxygenated blood in the working muscles rather than a redistribution of the cardiac output favoring the blood flow in these working muscles. The logical explanation for this more complete oxygen extraction is given by the biochemical changes observed in muscle tissue after physical conditioning. In animals, a two-fold increase in the activity of oxidative mitochondrial enzymes and an increase in the number and the size of the mitochondria have been demonstrated by Gollnick _et al_. (48) and Holloszy (60). Recently, it was shown by Morgan _et al_. (84) that similar changes also occur in human muscles after training.

Thus, the decrease in heart rate during submaximal work load found in this study for the three training groups can be attributed to either a decrease in cardiac output as a result of an increased arteriovenous oxygen difference or an increase in stroke volume to maintain a similar cardiac output or a combination of both effects. However, the increase in oxygen pulse at submaximal work load following training was not significant (Figure 8). Since the oxygen uptake did not change significantly at this work load (Figure 3), the slight increases in oxygen pulse were due to the lower heart rates. In any event, the increase in oxygen pulse would fail to clarify the controversy because it could have been due to either an increased arteriovenous oxygen difference or/and a larger stroke volume. However, according to Saltin (96) the effects of endurance training in young people should be represented by short-term and long-term adaptations. The long-term changes (i.e. physiologic capacities) are best exemplified by the increase in heart size and consequently in stroke volume, while the short-term (i.e. neurogenic) are best illustrated by a better distribution of the cardiac output and consequently a more complete extraction of the oxygenated blood in the working muscles and also a more effective use of the muscle mass during exercise. In the present study there was no significant difference in the

decreases of the heart rate between the three training groups following training. It seems that as long as the training heart rate is above 130 beats per minute, optimum decreases in heart rate at a given submaximal work load can be achieved with children. This training intensity corresponded to approximately 45% of the difference between resting and maximal rates. This finding is similar to the results of Hollman _et al_. (57) and Durnin et al. (38) who observed in adults that walks eliciting heart rate of 120-130 beats per minute resulted in a significant change in the heart rate response to a set amount of work. In spite of this lack of significant difference between the three training groups, it is evident, however (Figure 2), that the high intensity group T1 improved more than the medium and low intensity groups (T2 and T3 respectively). On the other hand, the training threshold necessary to improve the aerobic power is different from the stimulus which improved the heart rate; this is further discussed under the maximal oxygen uptake section.

The blood lactate concentration at the given submaximal work load decreased significantly ($P < .05$) in the T1 group but did not change substantially in the T2, T3 and the control groups (Figure 6). The 25% (from 16.8 to 12.0 mg%) decrease in the T1 group following training

is slightly lower than the decrease reported by Ekblom (40, 42), Saltin et al. (97), Robinson et al. (91) and Wenger (120), but similar to those obtained by Edwards et al. (39), Hartley et al. (54), Faulkner (44) and Williams (122). This significant decrease in blood lactate level occurred only in the T1 group which demonstrated a significant improvement in maximum oxygen uptake (Figure 11). This relation suggests that in untrained subjects, the lactate production at submaximal work load is a direct consequence of an insufficient aerobic energy supply. Assuming that the training intensity improves the aerobic power, one would also expect that a concomitant decrease in the involvement of the anaerobic energy yield would occur at a given submaximal work load. Astrand et al. (13) and Saltin (96) interpreted this decrease as an expression of a more effective oxygen transport during the beginning of the work, leading to a diminished anaerobic energy yield. Also, Ekblom et al. (40, 42) suggested that the increased arteriovenous oxygen difference after training could account for the decreased anaerobic metabolism at a given submaximal work load. Supporting this concept, Saltin et al. (99) mentioned that the training increases activation of red muscle fibres leading to a more efficient energy yield from aerobic processes. Furthermore, Hermansen (56) and Williams (122) demonstrated that the

lactate level in the blood starts to increase at a higher percentage of the maximal oxygen uptake in trained people. Studying the effect of training at the cellular level, Holloszy (60) reported that during moderate exercise, the rate of aerobic metabolism of pyruvate in the muscle of sedentary individuals is limited not only by the oxygen supply but also by the capacity of the mitochondria for pyruvate oxidation. A two-fold increase in the capacity to oxidize pyruvate in the muscles of rats subjected to a program of strenuous exercise has been demonstrated by Holloszy (60) and he suggests that the increase in respiratory activity induced in muscle by physical training could play a major role in decreasing lactate production during submaximal work.

Although the pulmonary ventilation did not change significantly at the submaximal work load, it is apparent (Figure 5) that there was a slight drop in the ventilatory volume due to training. There was also a small diminution in oxygen consumption following training (Figure 3). Astrand and Rodahl (13) reported that during submaximal work of relatively low intensity, the pulmonary ventilation per litre of oxygen consumed does not change substantially with training. This assumption is explained by the fact that during submaximal work, the level of ventilation is primary determined by the CO_2 production which is directly related to the 0_2 utilization. Apparently the

depth of respiration is increased somewhat, associated with a corresponding reduction in the respiratory rate (13). On the other hand, some studies (5, 33, 37, 42, 96) showed a decrease in pulmonary ventilation at submaximal work load following training. Since the blood lactate concentration is generally lower during submaximal work following training (higher pH of the blood), the respiratory drive is reduced resulting in a lower ventilatory volume. In this study, a decrease in blood lactate level to a greater extent in the T1 group compared to the T2, T3 and control groups (Figure 6) corresponded to a greater decrease of the pulmonary ventilation in this T1 group after training (Figure 5).

The ventilatory equivalent ($\dot{V}E/\dot{V}O_2$) at both submaximal and the maximal work loads did not change with training (Figures 7 and 15). The results in this study are similar to those reported by Saltin et al. (97, 99) and Hermansen (56) who failed to obtain any significant changes in the ventilatory equivalent over a training period. These investigators mentioned that the changes in pulmonary ventilation are directly proportional to the changes in oxygen consumption. Thus, the ratio of pulmonary ventilation to oxygen consumption remained unchanged both at maximal and submaximal work loads.

The maximal pulmonary ventilation increased slightly in the three training groups due to training (Figure 13), but this improvement was not statistically significant. The main factor responsible for this increase could be the increase in blood lactate level at maximal work following training. This increase in lactate contributes to a lower pH of the blood and/or a higher PCO_2 and, therefore, the chemoreceptors controlling the respiratory center are activated. It is apparent that a greater increase of lactate in T1 group (Figure 14) corresponded to a greater increase of pulmonary ventilation for this training group.

Over the six weeks of training, the maximal oxygen consumption increased significantly by 11% (from 46.68 to 51.74 ml per kg per minute) in the T1 group but remained substantially unchanged in the T2 and T3 training and control groups (Figure 11). This improvement in $M\dot{V}O_2$ is in line with many studies which have shown increases ranging from 5 to 30% following training (29, 33, 41, 44, 54, 86, 97, 118, 123). However, it seems ambiguous to compare the magnitude of improvement of $M\dot{V}O_2$ with others studies because the changes are related to the intensity, duration and frequency of training and also to the age of the subjects and their initial fitness levels. Ekblom (41) showed a 20% increase of $M\dot{V}O_2$ in the 11 year old boys after

a six month training program; the $M\dot{V}O_2$ of the control group did not change over the same period of time. In Daniel's study (32), fourteen boys, aged 10-15, did not increase their $M\dot{V}O_2$ relative to the body weight after twenty-two months of distance running. The 22% increase in $M\dot{V}O_2$ was accompanied by a 23% change in body weight. According to Andrew _et al_. (5), Douglas _et al_. (37), Ekblom _et al_. (40, 42) and Saltin _et al_. (97), the increased maximal oxygen uptake following training is partly due to an increased maximal cardiac output and partly due to a higher arteriovenous difference. Therefore, maximal heart rate is almost unchanged with training in young subjects (41, 54, 86, 88, 90 and this present study) (Figure 10), the increase in cardiac output is due to the increase in stroke volume. On the other hand, Rowell _et al_. (95) observed that the increase of $M\dot{V}O_2$ after two months of training was mainly due to an increased arteriovenous oxygen difference while the maximal cardiac output and stroke volume remained unchanged. The increased arteriovenous oxygen difference might be mainly due to an increase in blood flow in the working muscles and/or to a more complete extraction of the oxygenated blood. Donald _et al_. (36) agreed with this concept of more effective redistribution of cardiac output and found that during maximal exercise, approximately 4 litres per minute more

blood was distributed to active muscles in the sedentary subjects following training. Furthermore, Holloszy (60) suggested that there is, even during maximal exercise in normal muscle cells a capacity to utilize more oxygen than is transported by the circulatory system. However, the increase in $M\dot{V}O_2$ with training might be achieved in different ways depending on the age of the subjects. Hartley _et al_. (54) and Saltin _et al_. (98, 99), studying the effects of training with different age groups of subjects (20 to 50 years) demonstrated that the distribution changes of blood flow by training are minimized by the aging process, thus the improvement of $M\dot{V}O_2$ in older subjects can mainly take place by increasing the stroke volume and the cardiac output. In comparison with younger subjects their increase was partly due to a larger stroke volume and also to a higher arteriovenous oxygen difference. They concluded that the blood flow to the legs in middle-aged subjects only paralleled the increase in cardiac output following training. Considering the findings of Hartley (54) and Saltin (98, 99) regarding this aging effect on blood flow, it could be possible that the increase in $M\dot{V}O_2$ in children with training is due in major part to the increase in arteriovenous oxygen difference caused by the more effective distribution of cardiac output. The significant increase of the oxygen pulse for the T1 group after

training (Figure 16) was due to an increase of $M\dot{V}O_2$ in this same group while the maximum heart rate did not change. However, it remains impossible to determine if this increase of oxygen pulse resulted from a larger stroke volume or/and an increase of arteriovenous difference. The significant improvement of $M\dot{V}O_2$ in the T1 group only suggests a training threshold below which no increase of the aerobic power occurred in this age group of children. This training stimulus was found to be above 170 heart beats per minute. Hollman (57), Karvonen (67, 68), Faria (43), Roskamm (93), and Sharkey et al. (102, 103) have reported a training threshold above 150 beats per minute or above 60% of the difference between the resting and maximal heart rates, necessary to elicit an improvement in physical work capacity with adult subjects. It appears in this study that the training stimulus in children in terms of heart rate is higher than the one in adults, partly because their maximal heart rate is slightly higher, but also probably because the children are much more physically active in their day life than adult individuals. Expressed in percentage of the difference between the resting and maximal rates the training threshold in children is above 75% compared to 60% in adults.

Although the maximal blood lactate concentrations increased 21%, 13% and 5% (for the T1, T2 and T3 groups

respectively) over the six week training, this change was significant only in the T1 group (Figure 14). These increases of blood lactate at maximal work are similar to the results with adults reported by Cunningham (29), Ekblom (40, 42), Saltin (96, 97) and Williams (121, 122). To what extent this higher concentration of blood lactate following training may be due to an increase in physiological tolerance for lactic acid with its side effects, or a greater psychological ability to exert oneself, is not understood. Astrand and Rodahl (13) suggested that the enlargement of muscle fibers induced by training leading to an increase of muscular strength and also a higher maximum work load (Figure 7) must inevitably increase the energy demand from the anaerobic energy yield. In this study it seems that the training threshold necessary to improve the $M\dot{V}O_2$ (T1 group) also improved the anaerobic metabolism (Figures 11, 14). Because the T1 group was taxing the anaerobic energy processes to a larger extent throughout the training than the T2 and T3 groups which were working mostly aerobically, it was expected that the ability to tolerate the lactic acid in the blood was greater in the T1 group.

The primary objective of physical training is an increased capacity to perform physical work. The three training groups increased significantly ($P < .01$) their

maximal work loads by 25%, 23% and 21% (for the T1, T2 and T3 groups respectively) while the control group did not improve over the six week training program (Figure 9). Along with the increase in aerobic and anaerobic metabolism, there might have been expected a greater increase in the T1 group than in the T2 and T3 groups. But the small differences of 33 and 67 kpm per minute in the increases with training between T1-T2 groups and T1-T3 groups respectively were not significant. However, after a close analysis of the maximal work loads in the three training groups (Table IV and Figure 9) it appears that the average work load in the T1 group is much higher than the work load of the T2 and T3 groups at the pre-training test. This higher maximal work load in the T1 group can be attributed to the higher weight of this group compared to the T2 and T3 groups (Table 11). This difference might be an important factor explaining the non-significant greater increase in this group compared to the other two training groups. The groups were equated on the initial fitness level based on their $M\dot{V}O_2$ after the pre training test; and, therefore, if the subjects in this group T1, having a similar aerobic power than the subjects in T2 and T3 groups, started the training with a higher physical performance, it might have been more difficult for them to improve this performance than the T2 and T3 groups.

The same factor can be taken in account for the small difference in improvement between the T2 and T3 groups. However, this substantial increase of the physical performance in the T2 and T3 groups without any significant improvement of the aerobic power following training could be attributed partly to an increase of the leg muscle strength with training and also partly to the slight increase of the anaerobic metabolism for both groups (Figure 14).

CHAPTER V

SUMMARY AND CONCLUSIONS

The physical condition of thirty six volunteer children (aged from 11 to 13 years: mean = 12.5 years) was evaluated on a bicycle ergometer prior to and following a six week training program. The subjects worked at a fixed submaximal work load equal to 450 kpm per minute for four minutes before performing the maximal work load in both pre and post training tests. The subjects were ranked according to their maximal oxygen consumption in millilitre per minute and blocked into three levels of initial fitness. The twelve subjects in each fitness level were then randomly assigned, three to each of the four treatment conditions. Thus the four treatment groups were equated on initial fitness level as determined by maximum oxygen consumption relative to body weight. The first treatment group (T1) trained at a steady state heart rate of 170-180 beats per minute; the second treatment group (T2) trained at 150-160 beats per minute; the third treatment group (T3) trained at 130-140 beats per minute; and the fourth treatment group (T4) acted as a control. The training program consisted of pedalling on the bicycle

[illegible]

[illegible]

[illegible]

ergometer three times a week, each session lasting 12 minutes. The heart rate was monitored once a week permitting an adjustment of the work load to maintain the specified training heart rate. The work load required to elicit the pre-determined training heart rate became the individual's load for the following two training sessions in the same week.

The heart rates at the given submaximal work load were significantly ($P < .05$) lower for the three training groups but were unchanged in the control group following the six week training program. The heart rate decreased by 11%, 9% and 8% in the T1, T2 and T3 groups respectively. The difference between the three training groups, however, was not significant.

The blood lactate concentration at submaximal work load decreased significantly ($P < .05$) by 26% in the T1 group following training. No other significant changes were found with training.

At the submaximal work load, no significant changes following training were found in any groups for the oxygen consumption in ml per kg per minute nor in litres per minute, the pulmonary ventilation, the respiratory equivalent nor the oxygen pulse.

Maximum oxygen consumption in ml per kg per minute, blood lactate concentration and oxygen pulse were significantly ($P < .05$) higher in the T1 group at maximal work load after training. The $M\dot{V}O_2$ increased by 11%, blood lactate by 21% and oxygen pulse by 13% in the T1 group after the six weeks of training. No significant changes were found in the two other training and control groups at maximal work load following training.

No significant changes were found with training in any of the groups for the heart rate and ventilatory equivalent at maximal work load.

The maximal work loads were significantly ($P < .01$) higher in the three training groups following training. The T1, T2 and T3 groups increased their physical performance by 25%, 23% and 21% respectively with training. The difference between the three training groups, however, was not significant.

CONCLUSIONS

Since the three training groups showed similar substantial reductions in heart rate at a given submaximal work load following training it seems probable that any intensity of training (from 130 up to 180 heart beats per minute) would be suitable in reducing cardiac work at

submaximal work loads in this age group of children. The training threshold improving the submaximal heart rate seems to be approximately the same in children as in adult individuals.

Since the maximum heart rate remained unchanged after the training, it suggests that a relatively short period of training does not affect the maximal cardiac rhythm in this age group of children. This finding is also in agreement with most studies using adults as subjects.

Since the maximum oxygen consumption relative to body weight and also the maximum blood lactate level showed a significant ($P < .05$) improvement only in the T1 group following training, it would be appropriate to suggest that the training threshold necessary to improve the maximal aerobic and anaerobic powers should be above 170 heart beats per minute in this age group of children. This training stimulus corresponding to approximately 75% of the difference between the resting and maximum heart rates, appears to be higher in children than in adults.

Since the training program affected the submaximal heart rate similarly in the three different intensity groups without improving the maximal aerobic power in the

medium and low intensity training groups, it would be appropriate to suggest that the training stimulus improving the cardiac work does not necessarily improve the maximal aerobic power in children.

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APPENDIX A

ENZYMATIC MICROMETHOD FOR DETERMINING THE LACTIC ACID CONTENT OF FINGERTIP BLOOD

Between 45 and 60 seconds after each work load, blood was sampled from a finger-tip of a hand pre-heated in a water bath kept at 45-47°C. The finger-tip was cleaned with ether and, when the latter had evaporated, was pricked with a laviet. From suspended droplets, 0.1 ml of blood was first drawn into a heparinized and disposable "Micro Blood Collecting Pipets" holding 0.1 - 0.2 ml. The blood was transferred into a calibrated and disposable "Micro Pipet" holding exactly 0.1 ml, then immediately blown into a test tube which contained 0.2 ml of 8 percent cold perchloric acid. Blood and perchloric acid were carefully stirred. It was necessary to expel the blood directly into the perchloric acid and prevent its adhesion to the tube wall. Two fresh pipets for each blood sample were essential.

Following cenrifugation, 0.1 ml of the supernatant was taken with a Carlsberg pipet and transferred to a test tube containing 0.05 ml of LDH suspension, 5 mg B-DPN, 0.97 ml glycine hydrazine buffer: pH 9.2, and 1.94 ml water. These reagents were supplied from "Sigma Chemical Company," (Referred to Sigma Technical Bulletin No. 826-UV as a commercial kit). The mixture was incubated for 60 minutes at 25°C. and its extinction was determined, in relation to a blank test, at 340 mu by a recording Bausch

+ Lomb Spectronic 20. The blood lactic acid concentration was expressed in milligrams per hundred millilitres of blood (mg %).

APPENDIX B

STATISTICAL ANALYSIS OF DATA OBTAINED AT SUBMAXIMAL WORK LOAD (450 kpm/min) PRIOR TO AND FOLLOWING TRAINING

APPENDIX B-1

a) THREE WAY ANALYSIS OF VARIANCE FOR HEART RATE (beats per minute) AT SUBMAXIMAL WORK LOAD (450 kpm)

Summary Table:

Source	SS	DF	MS	F	P
Between Subjects	14482.00	35			
A	3758.00	3	1252.67	3.56	<.029
B	286.00	2	143.00	0.41	<.670
AB	1950.00	6	332.50	0.95	<.482
subj. w. grps.	8443.00	24	351.79		
Within Subjects	4614.00	36			
C	2091.00	1	2091.00	29.66	<.001
AC	1696.00	3	1163.33	19.76	<.001
BC	1.00	2	0.50	0.01	<.993
ABC	34.00	6	5.67	0.08	<.998
C x Subj. w. grps.	1692.00	24	70.50		

b) TEST FOR SIMPLE MAIN EFFECTS FOR HEART RATE (beats/min) AT SUBMAXIMAL WORK LOAD (450 kpm/min) AT PRE-TRAINING TEST

Source	SS	MS	DF	F	$_{32}^{3}F$ CRIT.
Groups	1981.94	660.65	3	3.51	.05=2.92
Error	6024.06	188.65	32		

c) NEWMAN-KEULS COMPARISON BETWEEN ORDERED MEANS FOR HEART RATE (beats/min) AT SUBMAXIMAL WORK LOAD (450 kpm/min) AT PRE-TRAINING TEST

Group Means	3(130-140) 168.67	2(150-160) 163.22	4(Control) 154.56	1(170-180) 149.56
1(170-180) 149.56	19.11*	13.67	5.00	-
4(Control) 154.56	14.11	8.66	-	-
2(150-160) 163.22	5.44	-		
3(130-140) 168.67	-			

*Significant at α .05

Critical Values	r=2	r=3	r=4
q .99 (r, 32)	13.16	15.90	17.54
q .95 (r, 32)	17.73	20.24	21.84

critical values = $\alpha qr \sqrt{\text{MS error}/N}$

d) THREE WAY ANALYSIS OF VARIANCE FOR HEART RATE (beats/minute) AT SUBMAXIMAL WORK LOAD (450 kpm/min)

Summary Table

Source	SS	DF	MS	F	P
Between Subjects	14482.00	35			
A	3758.00	3	1252.67	3.56	<.029
B	286.00	2	143.00	0.41	<.670
AB	1950.00	6	332.79	0.95	<.482
Subj. w grps.	3443.00	24	351.79		
Within Subjects	4614.00	36			
C	2091.00	1	2091.00	29.66	<.001
AC	796.00	3	263.33	3.71	<.024
BC	1.00	2	0.50	0.01	<.993
ABC	34.00	6	5.67	0.08	<.998
C x Subj. w. grps.	1692.00	24	70.50		

e) TEST FOR SIMPLE MAIN EFFECTS FOR HEART RATE (beats/min) AT SUBMAXIMAL WORK LOAD (450 kpm/min) AT POST TRAINING TEST

Source	SS	MS	DF	F	$^{3}F_{32}$ CRIT.
Groups	2571.75	857.25	3	4.27	.05=2.92
					.01=4.51
Error	6426.50	200.86	33		

APPENDIX B-1

f) NEWMAN-KEULS COMPARISON BETWEEN ORDERED MEANS FOR HEART RATE (beats/min) AT SUBMAXIMAL WORK LOAD (450 kpm/min) AT POST-TRAINING TEST

Group Means	4(Control) 155.00	3(130-140) 153.00	2(150-160) 151.11	1(170-180) 133.78
1(170-180) 133.78	21.22**	19.22*	17.33*	-
2(150-160) 151.11	3.89	1.89	-	
3(130-140)	2.00	-		
4(Control)	-			

** Significant at α .01
* Significant at α .05

Critical values	r=2	r=3	r=4
q .95 (r,32)	13.59	16.42	18.12
q .99 (r,32)	18.31	20.90	22.56

$$\text{critical values} = \alpha q r \sqrt{\text{MS error}/N}$$

g) SCHEFFE CONTRAST COMPARISON BETWEEN ORDERED MEAN DIFFERENCES FOR HEART RATE (beats/min) AT SUBMAXIMAL WORK LOAD (450 kpm/min) AT PRE AND POST-TRAINING TESTS

Group Mean Differences	D_1(170-180) 15.78	D_3(130-140) 13.67	D_2(150-160) 12.12	D_4(Control) -0.44
D_4(Control) (0.44)	20.85*	19.83*	17.02*	-
D_2(150-160) 12.12	1.07	0.82	-	
D_3(130-140) 13.67	0.09	-		
D_1(170-180) 15.78	-			

* Significant at α .05

Critical Values 7 $^{7}F_{24}$

q .95 K - 1 (7, 24) = 16.95

q .99 K - 1 (7, 24) = 24.50

APPENDIX B-11

a) THREE WAY ANALYSIS OF VARIANCE FOR OXYGEN CONSUMPTION (millilitres per kg of body weight per minute) AT SUB-MAXIMAL WORK LOAD (450 kpm)

Summary Table:

Source	SS	DF	MS	F	P
Between Subjects	1640.04	35			
A	194.05	3	64.68	1.40	<.266
B	173.75	2	86.88	1.88	<.174
AB	165.65	6	27.61	0.60	<.728
Subj. w. grps.	1106.58	24	46.11		
Within Subjects	154.90	36			
C	29.45	1	29.45	6.87	<.015
AC	6.37	3	2.12	0.50	<.689
BC	8.78	2	4.39	1.02	<.374
ABC	7.48	6	1.25	0.29	<.935
C x Subj. w. grps.	102.84	24	4.28		

[illegible]

[illegible]

[illegible]

APPENDIX B-111

a) THREE WAY ANALYSIS OF VARIANCE FOR OXYGEN CONSUMPTION (litres per minute) AT SUBMAXIMAL WORK LOAD (450 kpm)

Summary Table:

Source	SS	DF	MS	F	P
Between Subjects	0.874	35			
A	0.030	3	0.010	0.35	<.786
B	0.006	2	0.003	0.10	<.905
AB	0.177	6	0.030	1.07	<.409
Subj. w. grps.	0.662	24	0.028		
Within Subjects	0.211	36			
C	0.030	1	0.030	5.16	<.032
AC	0.010	3	0.003	0.58	<.632
BC	0.011	2	0.006	1.03	<.371
ABC	0.025	6	0.004	0.73	<.633
C x Subj. w. grps.	0.136	24	0.006		

APPENDIX B-lV

a) THREE WAY ANALYSIS OF VARIANCE FOR VENTILATION (litres per minute STPD) AT SUBMAXIMAL WORK LOAD (450 kpm)

Summary Table:

Source	SS	DF	MS	F	P
Between Subjects	1712.75	35			
A	42.50	3	14.17	0.26	<.857
B	116.75	2	58.38	1.05	<.365
AB	221.50	6	36.92	0.67	<.678
Subj. w. grps.	1332.00	24	55.50		
Within Subjects	352.50	36			
C	37.56	1	37.56	3.83	<.062
AC	51.50	3	17.17	1.75	<.183
BC	7.94	2	3.97	0.40	<.671
ABC	20.25	6	3.38	0.34	<.906
C x Subj. w. grps.	235.25	24	9.80		

APPENDIX B-V

a) THREE WAY ANALYSIS OF VARIANCE FOR BLOOD LACTATE CONCENTRATION (milligrams per hundred millilitres of blood) AT SUBMAXIMAL WORK LOAD (450 kpm)

Summary Table:

Source	SS	DF	MS	F	P
Between Subjects	2781.61	35			
A	905.95	3	301.98	6.36	<.002
B	70.03	2	35.01	0.74	<.489
AB	666.64	6	111.11	2.34	<.064
Subj. w. grps.	1139.00	24	47.46		
Within Subjects	671.00	36			
C	180.50	1	180.50	12.80	<.001
AC	42.39	3	14.13	1.00	<.409
BC	55.75	2	27.88	1.98	<.160
ABC	54.03	6	9.00	0.64	<.698
C x Subj. w. grps.	338.34	24	14.10		

b) TEST FOR SIMPLE MAIN EFFECTS FOR BLOOD LACTATE CONCENTRATIONS (mg/100 ml of blood) AT SUBMAXIMAL WORK LOAD (450 kpm/min) AT POST-TRAINING TEST

Source	SS	MS	DF	F	$^{3}F_{32}$ CRIT.
Groups	667.00	222.33	3	8.95	.05=2.92 .01=5.41
Error	794.89	24.84	32		

APPENDIX B-V

c) NEWMAN-KEULS COMPARISON BETWEEN ORDERED MEANS FOR BLOOD LACTATE CONCENTRATIONS (mg/100 mls of blood) AT SUB-MAXIMAL WORK LOAD (450 kpm/min) AT POST-TRAINING TEST

Group Means	4(Control) 22.89	3(130-140) 19.33	2(150-160) 14.00	1(170-180) 12.00
1(170-180) 12.00	10.89**	7.33**	2.00	-
2(150-160) 14.00	8.88**	5.33*	-	
3(130-140) 19.33	3.56	-		
4(Control) 22.89	-			

** Significant at α .01
* Significant at α .05

Critical values	r=2	r=3	r=4
q .99 (r,32)	4.78	5.77	6.37
q .95 (r,32)	6.44	7.32	7.93

critical values = $\alpha q r \sqrt{\text{MS error}/N}$

APPENDIX B-V

d) SCHEFFE CONTRAST COMPARISON BETWEEN ORDERED MEAN DIFFERENCES FOR BLOOD LACTATE CONCENTRATIONS (mg/100 ml of blood) AT SUBMAXIMAL WORK LOAD (450 kpm/min) AT PRE AND POST TRAINING TESTS

Group Mean Differences	D_1(170-180) 4.78	D_2(150-160) 2.40	D_3(130-140) 2.11	D_4(Control) 1.21
D_4(Control) 1.21	17.08*	10.11	9.26	-
D_3(130-140) 2.11	13.28	1.92	-	
D_2(150-160) 2.40	2.09	-		
D_1(170-180) 4.78	-			

*Significant at α .05

Critical values $7\ {}^{7}F_{24}$

q .95 K - 1 (7, 24) = 16.94

q .99 K - 1 (7, 24) = 24.50

APPENDIX B-VI

a) THREE WAY ANALYSIS OF VARIANCE FOR VENTILATION EQUIVALENT (ventilation in litres per minute divided by oxygen consumption in litres per minute) AT SUBMAXIMAL WORK LOAD (450 kpm)

Summary Table:

Source	SS	DF	MS	F	P
Between Subjects	1653.54	35			
A	23.21	3	7.74	0.19	<.903
B	119.71	2	59.85	1.46	<.252
AB	526.94	6	87.82	2.14	<.085
Subj. w. grps.	983.68	24	40.99		
Within Subjects	172.86	36			
C	1.85	1	1.85	0.38	<.541
AC	30.36	3	10.12	2.10	<.126
BC	1.78	2	0.89	0.18	<.833
ABC	23.31	6	3.88	0.81	<.575
C x Subj. w. grps.	115.57	24	4.82		

APPENDIX B-VII

a) THREE WAY ANALYSIS OF VARIANCE FOR OXYGEN PULSE (millilitres of oxygen per heart beat) AT SUB-MAXIMAL WORK LOAD (450 kpm)

Summary Table:

Source	SS	DF	MS	F	P
Between Subjects	84.15	35			
A	18.21	3	6.07	3.01	< .050
B	1.71	2	0.85	0.42	< .660
AB	15.78	6	2.63	1.30	< .294
Subj. w. grps.	48.45	24	2.02		
Within Subjects	11.27	36			
C	2.16	1	2.16	8.09	< .008
AC	1.36	3	0.45	1.70	< .193
BC	0.53	2	0.27	1.00	< .383
ABC	0.82	6	0.14	0.51	< .792
C x Subj. w. grps.	6.40	24	0.27		

b) TEST FOR SIMPLE MAIN EFFECTS FOR OXYGEN PULSE (millilitres per heart beat) BETWEEN TREATMENTS AT SUBMAXIMAL WORK LOAD (450 kpm/min) AT PRE-TRAINING TEST

Source	SS	MS	F	F	${}^{3}_{32}F$ CRIT.
Groups	9.72	3.24	3	3.02	.05=2.92 .01=5.41
Error	34.29	1.07	32		

[illegible]

APPENDIX B-VII

c) NEWMAN-KEULS COMPARISON BETWEEN ORDERED MEANS FOR OXYGEN PULSE (ml/H.B.) AT SUBMAXIMAL WORK LOAD (450 kpm/min) AT PRE-TRAINING TEST

Group Means	1(170-180) 8.10	4(Control) 7.52	2(150-160) 6.99	3(130-140) 6.75
3(130-140) 6.75	1.35**	0.77**	0.24	-
2(150-160) 6.99	1.11**	0.53**	-	
4(Control) 7.52	0.58**	-		
1(170-180) 8.10	-			

** Significant at α .01

Critical values	r=2	r=3	r=4
q .95 (r,32)	0.31	0.38	0.42
q .99 (r,32)	0.42	0.48	0.52

critical values = $\alpha qr \sqrt{\text{MS error}/N}$

APPENDIX B-VII

d) SCHEFFE CONTRAST COMPARISON BETWEEN ORDERED MEAN DIFFERENCES FOR OXYGEN PULSE (ml/H.B.) AT SUBMAXIMAL WORK LOAD (450 kpm/min) AT PRE AND POST-TRAINING TESTS

Group Mean Differences	D_2(150-160) 0.54	D_1(170-180) 0.47	D_3(130-140) 0.46	D_4(Control) -1.01
D_4(Control) -1.01	8.54	5.70	5.70	-
D_3(130-140) 0.46	0.28	0.00	-	
D_1(170-180) 0.47	0.28	-		
D_2(150-160) 0.54	-			

No significant difference

Critical values $7 \; {}^{7}F_{24}$

q .95 K - 1 (7, 24) = 16.94

q .99 K - 1 (7, 24) = 24.50

APPENDIX C

STATISTICAL ANALYSIS FOR DATA OBTAINED AT MAXIMAL WORK LOADS PRIOR TO AND FOLLOWING TRAINING

APPENDIX C-1

a) THREE WAY ANALYSIS OF VARIANCE FOR WORK LOADS AT MAXIMUM OXYGEN CONSUMPTION (kpm per min)

Summary Table:

Source	SS	DF	MS	F	P
Between Subjects	1450944.00	35			
A	405952.00	3	135317.31	3.77	<.024
B	56896.00	2	28448.00	0.79	<.465
AB	125536.00	6	20922.66	0.58	<.741
Subj. w. grps.	862560.00	24	35940.00		
Within Subjects	708624.00	36			
C	475328.00	1	475328.00	218.11	<.001
AC	168400.00	3	56133.33	25.76	<.001
BC	1856.00	2	928.00	0.43	<.658
ABC	10736.00	6	1789.33	0.82	<.565
C x Subj. w. grps.	52304.00	24	2179.33		

b) TEST FOR SIMPLE MAIN EFFECTS FOR MAXIMUM WORK LOADS (kpm/min) BETWEEN TREATMENTS AT PRE-TRAINING TEST

Source	SS	MS	DF	F	$^{3}F_{32}$ CRIT.
Groups	141888.00	47296.00	3	3.15	.05=2.92
Error	479984.00	14999.50	32		.05=4.51

APPENDIX C-1

c) NEWMAN-KEULS COMPARISON BETWEEN ORDERED MEANS FOR MAXIMUM WORK LOADS (kpm/min) AT PRE-TRAINING TEST

Group Means	1(170-180) 1000.00	4(Control) 966.67	2(150-160) 916.67	3(130-140) 833.33
3(130-140) 833.33	166.67*	133.33	83.33	-
2(130-140) 916.67	83.33	50.00	-	
4(Control) 966.67	33.33	-		
1(170-180) 1000.00	-			

* Significant at α .05

Critical values	r=2	r=3	r=4
q .95 (r, 32)	117.56	142.05	156.74
q .99 (r, 32)	158.38	156.74	195.11

critical values = $\alpha qr \sqrt{\text{MS error}/N}$

APPENDIX C-1

d) THREE WAY ANALYSIS OF VARIANCE FOR WORK LOADS AT MAXIMUM OXYGEN CONSUMPTION (kpm per min)

Summary Table:

Source	SS	DF	MS	F	P
Between Subjects	1450944.00	35			
A	405952.00	3	135317.31	3.77	<.024
B	56896.00	2	28448.00	0.79	<.465
AB	125536.00	6	20922.66	0.58	<.741
Subj. w. grps.	862560.00	24	35940.00		
Within Subjects	708624.00	36			
C	475328.00	1	475328.00	218.11	<.001
AC	168400.00	3	56133.00	25.76	<.001
BC	1856.00	2	928.00	0.43	<.658
ABC	10736.00	6	1789.00	0.82	<.565
C x Subj. w. grps.	52304.00	24	2179.00		

e) TEST FOR SIMPLE MAIN EFFECTS FOR MAXIMUM WORK LOADS (kpm/min) BETWEEN TREATMENTS AT POST-TRAINING TEST

Source	SS	MS	DF	F	$^{3}_{32}$F. CRIT.
Groups	432496.00	144165.31	3	7.32	.05=2.92 .01=4.51
Error	629984.00	19687.00	32		

APPENDIX C-1

f) NEWMAN-KEULS COMPARISON BETWEEN ORDERED MEANS FOR MAXIMUM WORK LOADS (kpm/min) AT POST-TRAINING TEST

Group Means	1(170-180) 1250.00	2(150-160) 1133.33	3(130-140) 1016.68	4(Control) 966.67
4(Control) 966.67	283.33**	166.67*	50.00	-
3(130-140) 1016.67	233.33**	116.67	-	
2(150-160) 1133.33	116.67	-		
1(170-180) 1250.00	-			

** Significant at α .01
* Significant at α .05

Critical values	r=2	r=3	r=4
q .95 (r, 32)	134.69	162.75	179.59
q .99 (r, 32)	181.46	207.19	223.56

critical values = $\alpha qr \sqrt{\text{MS error}/N}$

APPENDIX C-1

g) SCHEFFE CONTRAST COMPARISON BETWEEN ORDERED MEAN DIFFERENCES FOR MAXIMUM WORK LOADS (kpm/min) AT PRE AND POST TRAINING TESTS

Group Mean Differences	D_1(170-180) 250.00	D_2(150-160) 216.67	D_3(130-140) 183.34	D_4Control) 00.00
D_4(Control) 00.00	129.07**	96.95**	69.41**	-
D_3(130-140) 183.34	9.18	2.29	-	
D_2(150-160) 216.67	2.29	-		
D_1(170-180) 250.00	-			

** Significant at α .01

Critical values $7\ {}^{7}F_{24}$

q .95 K - 1 (7, 24) = 16.94

q .99 K - 1 (7, 24) = 24.50

[illegible]

APPENDIX C-11

a) THREE WAY ANALYSIS OF VARIANCE FOR MAXIMUM HEART RATE (beats per minute)

Summary Table:

Source	SS	DF	MS	F	P
Between Subjects	2205.00	35			
A	103.00	3	34.33	0.47	< .704
B	3.00	2	1.50	0.02	< .980
AB	359.00	6	59.83	0.83	< .562
Subj. w. grps.	1740.00	24	72.50		
Within Subjects	353.00	36			
C	-	1	-	-	-
AC	22.00	3	7.33	0.71	< .554
BC	3.00	2	1.50	0.15	< .865
ABC	81.00	6	13.50	1.31	< .290
C x Subj. w. grps.	247.00	24	10.29		

APPENDIX C-111

a) THREE WAY ANALYSIS OF VARIANCE FOR MAXIMUM OXYGEN CONSUMPTION (millilitres per kilogram of body weight per minute)

Summary Table:

Source	SS	DF	MS	F	P
Between Subjects	2167.63	35			
A	170.94	3	56.98	2.30	<.103
B	1315.19	2	657.59	26.54	<.001
AB	86.75	6	14.46	0.58	<.740
Subj. w. grps.	594.75	24	24.78		
Within Subjects	266.94	36			
C	38.00	1	38.00	14.03	<.001
AC	100.06	3	33.25	12.32	<.001
BC	47.94	2	23.97	8.85	<.001
ABC	15.94	6	2.66	0.98	<.460
C x Subj. w. grps.	65.00	24	2.71		

b) TEST FOR SIMPLE MAIN EFFECTS FOR MAXIMUM OXYGEN CONSUMPTION (ml/kg/min) BETWEEN TREATMENTS AT POST-TRAINING TEST

Source	SS	MS	DF	F	${}^{3}_{32}F$ CRIT.
Groups	256.63	85.54	3	3.62	.05=2.92 .01=4.51
Error	756.38	23.64	32		

[illegible]

APPENDIX C-111

c) NEWMAN-KEULS COMPARISON BETWEEN ORDERED MEANS FOR MAXIMUM OXYGEN CONSUMPTION (millilitres per kilogram of body weight per minute) AT POST-TRAINING TEST

Group Means	1(170-180) 51.74	3(130-140) 48.24	2(150-160) 48.00	4(Control) 44.19
4(Control) 44.19	7.54*	4.05	3.81	-
2(150-160) 48.00	3.74	0.24	-	
3(130-140) 48.24	3.49	-		
1(170-180) 51.74	-			

* Significant at α .05

Critical values	r=2	r=3	r=4
q .95 (r, 32)	4.63	5.60	6.18
q .99 (r, 32)	6.24	7.13	7.69

critical values = $\alpha qr \sqrt{\text{MS error}/N}$

APPENDIX C-IV

a) THREE WAY ANALYSIS OF VARIANCE FOR MAXIMUM OXYGEN CONSUMPTION (litres per minute)

Summary Table:

Source	SS	DF	MS	F	P
Between Subjects	8.62	35			
A	1.83	3	0.61	2.43	< .090
B	0.30	2	0.15	0.60	< .557
AB	0.48	6	0.08	0.32	< .919
Subj. w. grps.	6.00	24	0.25		
Within Subjects	0.73	36			
C	0.18	1	0.18	24.70	< .001
AC	0.20	3	0.07	9.12	< .001
BC	0.13	2	0.07	9.13	< .001
ABC	0.04	6	0.007	0.95	< .479
C x Subj. w. groups	0.17	24	0.007		

b) TEST FOR SIMPLE MAIN EFFECTS FOR MAXIMUM OXYGEN CONSUMPTION (litres per minute) BETWEEN TREATMENTS AT POST-TRAINING TEST

Source	SS	MS	DF	F	$^{3}F_{32}$.CRIT.
Groups	1.35	0.45	3	4.13	.05=2.92 .01=4.51
Error	3.47	0.11	32		

APPENDIX C-IV

c) NEWMAN-KEULS COMPARISON BETWEEN ORDERED MEANS FOR MAXIMUM OXYGEN CONSUMPTION (litres per minute) AT POST-TRAINING TEST

Group	1(170-180)	4(Control)	2(150-160)	3(130-140)
Means	2.29	1.94	1.90	1.77
3(130-140) 1.77	0.52**	0.17	0.13	-
2(150-160) 1.90	0.39*	0.04	-	
4(Control) 1.94	0.35*	-		
1(170-180) 2.29	-			

** Significant at α .01
 * Significant at α .05

Critical values	r=2	r=3	r=4
q .95 (r, 32)	0.28	0.34	0.38
q .99 (r, 32)	0.38	0.44	0.47

$$\text{critical values} = \alpha qr \sqrt{\text{MS error}/N}$$

APPENDIX C-V

a) THREE WAY ANALYSIS OF VARIANCE FOR MAXIMUM PULMONARY VENTILATION (litres per minute, STPD)

Summary Table:

Source	SS	DF	MS	F	P
Between Subjects	8648.50	35			
A	1332.00	3	444.00	1.62	< .211
B	473.13	2	236.56	0.86	< .435
AB	257.88	6	42.98	0.16	< .986
Subj. w. grps.	6585.50	24	274.40		
Within Subjects	820.81	36			
C	199.00	1	199.00	11.57	< .002
AC	13.69	3	4.56	0.27	< .850
BC	96.88	2	48.44	2.82	< .080
ABC	98.63	6	16.44	0.96	< .475
C x Subj. w. grps.	412.63	24	17.19		

APPENDIX C-VI

a) THREE WAY ANALYSIS OF VARIANCE FOR BLOOD LACTATE CONCENTRATIONS AT MAXIMAL WORK LOAD (milligrams per hundred millilitres of blood)

Summary Table:

Source	SS	DF	MS	F	P
Between Subjects	20229.18	35			
A	1077.50	3	359.17	0.66	< .583
B	3489.37	2	1744.69	3.22	< .058
AB	2657.94	6	442.99	0.82	< .567
Subj. w. grps.	13004.37	24	541.85		
Within Subjects	4086.50	36			
C	1503.31	1	1503.31	17.37	< .001
AC	335.94	3	111.98	1.29	< .299
BC	61.06	2	30.53	0.35	< .706
ABC	108.81	6	18.14	0.21	< .970
C x Subj. w. grps.	2077.63	24	86.57		

[illegible]

APPENDIX C-VI

b) SCHEFFE CONTRAST COMPARISON BETWEEN ORDERED MEAN DIFFERENCES FOR BLOOD LACTATE CONCENTRATIONS (mg/100 ml of blood) AT MAXIMUM WORK LOAD AT PRE AND POST TRAINING TESTS

Group Mean Differences	D_1(170-180) 15.11	D_2(150-160) 11.00	D_3(130-140) 6.78	D_4(Control) 3.67
D_4(Control) 3.67	17.80*	13.80	7.50	-
D_3(130-140) 6.78	10.61	8.93	-	
D_2(150-160) 11.00	7.88	-		
D_1(170-180) 15.11	-			

* Significant at α .05

Critical values $7 \; F^{7}_{24}$

q	.95	K - 1	(7, 24)	=	16.94
q	.99	K - 1	(7, 24)	=	24.50

APPENDIX C-VII

a) THREE WAY ANALYSIS OF VARIANCE FOR VENTILATORY EQUIVALENT (ventilation in litres per minute divided by the oxygen consumption in litres per minute) AT MAXIMAL WORK LOAD

Summary Table:

Source	SS	DF	MS	F	P
Between Subjects	938.15	35			
A	18.81	3	6.27	0.18	$<.909$
B	44.88	2	22.44	0.65	$<.533$
AB	36.69	6	6.61	0.19	$<.977$
Subj. w. grps.	834.75	24	34.78		
Within Subjects	156.63	36			
C	-	1	-	-	-
AC	23.13	3	7.71	1.67	$<.199$
BC	5.50	2	2.75	0.60	$<.558$
ABC	17.44	6	2.91	0.63	$<.704$
C x Subj. w. grps.	110.56	24	4.61		

APPENDIX C-VII

a) THREE WAY ANALYSIS OF VARIANCE FOR OXYGEN PULSE (millilitres of oxygen per heart beat) AT MAXIMAL WORK LOAD

Summary Table:

Source	SS	DF	MS	F	P
Between Subjects	232.04	35			
A	49.09	3	16.36	2.45	< .088
B	7.80	2	3.90	0.58	< .566
AB	14.61	6	2.43	0.36	< .894
Subj. w. grps.	160.54	24	6.69		
Within Subjects	2.33	36			
C	3.30	1	3.30	9.23	< .005
AC	7.37	3	2.46	6.88	< .001
BC	2.96	2	1.48	4.15	< .028
ABC	1.13	6	0.19	0.53	< .782
C x Subj. w. grps.	8.57	24	0.36		

b) TEST FOR SIMPLE MAIN EFFECTS FOR OXYGEN PULSE (millilitres per heart beat) BETWEEN TREATMENTS AT MAXIMAL WORK LOAD AT POST-TRAINING TEST

Source	SS	MS	DF	F	${}^{3}F_{32}$ CRIT.
Group	35.98	11.99	3	3.97	.05=2.92
Error	96.73	3.02	32		.01=4.51

APPENDIX C-VIII

c) NEWMAN-KEULS COMPARISON BETWEEN ORDERED MEANS FOR OXYGEN PULSE (mls/H.B.) AT MAXIMAL WORK LOAD AT POST-TRAINING TEST

Group	1(170-180)	4(Control)	2(150-160)	3(130-140)
Means	11.77	9.92	9.73	9.08
3(130-140) 9.08	2.69*	0.83	0.64	-
2(150-160) 9.73	2.05*	0.19	-	
4(Control) 9.92	1.85*	-		
1(170-180) 11.70	-			

* Significant at α .05

Critical values	r=2	r=3	r=4
q .95 (r, 32)	1.64	1.98	2.18
q .99 (r, 32)	2.21	2.52	2.72

critical values = $\alpha qr\sqrt{\text{MS error}/N}$

APPENDIX D

AVERAGE WORK LOAD PERFORMED BY EACH TRAINING GROUP OVER THE SIX WEEK TRAINING PROGRAM IN KILOPOND METRES PER MINUTE

Training Groups	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Group (T1) 170-180 HR.	615.00	657.00	724.98	791.64	866.64	924.99
Group (T2) 150-160HR.	408.33	458.31	525.00	574.98	624.99	666.66
Group (T3) 130-140 HR.	258.33	308.31	358.32	400.00	450.00	508.32

APPENDIX E

AVERAGE WORK LOAD PERFORMED BY EACH FITNESS LEVEL OVER THE SIX WEEK TRAINING PROGRAM IN KILOPOND METRES PER MINUTE

Fitness Levels	Week 1	Week 2	Week 3	Week 4	Week 6	Week 6
High	458.31	525.00	583.32	641.64	691.65	758.31
Medium	391.65	416.64	499.98	549.99	608.31	675.00
Low	343.31	397.51	458.04	518.00	575.45	645.68

APPENDIX F

EXPERIMENTAL DESIGN

Randomized Block Design

Fixed Model

Repeated Measures on Factor C

Winer (120) pp. 337

Treatment Groups	Blocks (Initial Fitness Levels)	Time (Pre and Post-Training)	
		C_1 (Pre)	C_2 (Post)
A_1 (N=9) T_1 (170-180 Hr.)	B_1 (n=3)		
	B_2 (n=3)		
	B_3 (n=3)		
A_2 (N=9) T_2 (150-160 Hr.)	B_1 (n=3)		
	B_2 (n=3)		
	B_3 (n=3)		
A_3 (N=9) T_3 (130-140 Hr.)	B_1 (n=3)		
	B_2 (n=3)		
	B_3 (n=3)		
A_4 (N=9) T_4 (Control)	B_1 (n=3)		
	B_2 (n=3)		
	B_3 (n=3)		

APPENDIX G

RAW SCORES OBTAINED DURING SUBMAXIMAL AND MAXIMAL WORK LOADS AT PRE-TRAINING TEST

RAW SCORES OBTAINED DURING MAXIMAL WORK LOAD AT PRE-TRAINING TEST

Subjects	HR	$\%O_2$	$\%CO_2$	$\dot{V}E$ (STPD)	LACTATE (mg%)	$\dot{V}O_2$ (ml/kg/min)
T_1(170-180)						
1	155	16.53	3.8	33.37	13	23.98
2	150	17.05	3.5	35.00	13	20.48
3	141	17.11	3.6	33.37	17	28.37
4	129	16.63	4.2	26.83	14	27.85
5	118	16.48	4.5	20.35	16	27.59
6	167	17.38	3.5	36.26	11	35.67
7	161	18.08	3.0	36.63	24	31.62
8	180	18.04	3.2	42.33	28	35.51
9	145	18.53	2.7	41.51	15	22.21
T_2(150-160)						
1	173	17.60	3.6	35.65	28	26.97
2	161	17.50	3.1	38.26	15	36.63
3	170	17.18	4.2	29.68	27	20.52
4	173	17.35	3.6	28.90	21	32.53
5	155	17.13	3.6	31.71	11	25.69
6	180	16.22	3.3	39.99	21	39.40
7	158	17.48	3.5	25.94	13	28.13
8	154	16.55	3.9	27.64	13	26.40
9	155	17.00	3.7	22.79	18	30.85
T_3(130-140)						
1	176	16.73	3.9	20.73	11	26.11
2	158	16.95	4.0	25.23	17	28.23

Subjects	HR	%O	$\%CO_2$	$\dot{V}E$ (STPD)	LACTATE (mg%)	$\dot{V}O_2$ (ml/kg/min)
3	180	16.93	4.1	25.64	24	34.08
4	184	17.50	3.5	34.11	23	34.67
5	155	16.15	4.2	26.05	32	27.76
6	150	17.97	3.0	39.07	17	35.73
7	167	17.83	3.2	38.67	30	34.56
8	184	17.13	3.8	30.89	16	34.11
9	164	17.80	3.4	37.40	23	28.03
T_4 (Control)						
1	150	17.33	3.7	36.63	16	32.12
2	141	17.00	3.6	27.68	13	27.23
3	145	16.83	3.8	30.89	20	20.65
4	158	17.13	3.8	30.93	22	28.84
5	173	17.93	2.9	41.92	22	34.62
6	164	17.88	3.7	34.15	28	22.87
7	155	17.28	3.7	30.49	23	24.99
8	150	17.38	3.3	27.68	31	24.56
9	155	17.58	3.4	34.15	42	31.47

RAW SCORES OBTAINED DURING MAXIMAL WORK LOAD AT PRE-TRAINING TEST

Subjects	HR	$\%O_2$	$\%CO_2$	$\dot{V}E$ (STPD)	LACTATE (mg%)	$\dot{V}O_2$ (ml/kg/min)
T_1(170-180)						
1	195	17.48	3.9	74.88	82	45.93
2	195	18.18	3.2	83.03	75	32.21
3	200	17.48	3.9	82.05	78	58.63
4	187	17.53	3.8	64.23	74	50.81
5	187	17.15	2.9	38.26	87	39.35
6	195	18.05	3.2	59.19	49	45.63
7	187	18.05	3.2	54.54	62	46.71
8	200	18.10	3.1	63.49	65	51.52
9	195	17.93	3.4	74.07	73	49.37
T_2(150-160)						
1	200	18.25	3.2	71.31	95	41.11
2	195	17.25	3.5	56.98	97	57.81
3	204	17.55	4.2	52.85	79	31.78
4	214	17.88	3.6	54.95	104	50.40
5	191	17.75	3.6	79.67	64	51.36
6	195	17.45	3.7	52.01	120	43.91
7	200	17.33	3.9	39.59	50	43.98
8	187	17.25	4.0	64.23	93	48.95
9	195	18.03	3.1	54.54	80	52.82
T_3(130-140)						
1	187	17.65	3.6	54.88	108	51.57
2	200	17.63	4.1	67.56	93	51.67

Subjects	HR	$\%O_2$	$\%CO_2$	$\dot{V}E$ (STPD)	LACTATE (mg%)	$\dot{V}O_2$ (ml/kg/min)
3	-	-	-	56.07	83	41.83
4	200	17.88	3.4	56.17	40	49.62
5	195	17.23	4.4	45.58	80	34.70
6	195	17.95	2.9	58.61	101	55.43
7	-	-	-	55.85	84	45.74
8	195	17.48	3.9	48.78	106	47.23
9	195	17.63	3.7	52.60	70	41.25
T_4 (Control)						
1	214	18.25	3.5	77.33	104	46.70
2	187	17.63	3.7	58.61	68	45.96
3	200	17.33	4.0	75.61	94	42.29
4	195	17.38	3.9	53.72	74	45.59
5	195	17.96	3.8	59.42	82	49.42
6	195	17.28	3.6	76.42	109	47.70
7	187	17.50	3.7	51.22	52	38.71
8	187	17.70	3.3	56.98	72	44.84
9	187	17.73	3.7	58.54	95	49.61

APPENDIX H

RAW SCORES OBTAINED DURING SUBMAXIMAL AND MAXIMAL WORK LOADS AT POST TRAINING TEST

RAW SCORES OBTAINED DURING SUBMAXIMAL WORK LOAD AT POST-TRAINING TEST

Subjects	HR	$\%O_2$	$\%CO_2$	$\dot{V}E$ (STPD)	LACTATE (mg%)	$\dot{V}O_2$ (ml/kg/min)
T_1(170-180)						
1	132	16.53	4.1	26.20	10	21.58
2	122	16.13	4.4	25.35	9	17.82
3	123	16.58	4.1	28.56	14	27.51
4	118	16.38	4.4	23.07	10	24.60
5	120	16.73	4.1	20.04	10	25.66
6	150	17.06	3.2	31.08	12	34.64
7	134	18.08	3.1	35.49	14	30.77
8	164	17.78	3.2	36.54	17	33.77
9	141	18.30	3.8	40.96	12	20.57
T_2(150-160)						
1	145	17.98	2.5	34.28	19	24.73
2	134	17.13	3.7	29.40	10	29.96
3	145	16.73	4.0	26.82	17	21.40
4	167	17.35	3.5	29.40	18	31.54
5	132	17.23	3.7	31.27	14	24.80
6	164	17.46	4.0	36.96	22	40.06
7	173	17.15	3.7	29.57	18	33.95
8	145	16.70	4.0	26.88	12	23.76
9	155	16.70	4.3	24.51	16	34.46
T_3(130-140)						
1	161	17.25	3.9	28.73	14	30.59
2	136	17.18	3.8	26.78	12	24.73

Subjects	HR	$\%O_2$	$\%CO_2$	$\dot{V}E$ (STPD)	LACTATE (mg%)	VO_2 (ml/kg/min)
3	176	17.75	3.4	34.19	22	34.12
4	170	17.40	3.7	31.92	23	32.71
5	134	15.83	4.5	22.68	22	25.06
6	143	17.95	3.2	36.34	20	31.14
7	145	17.65	3.4	33.60	25	30.04
8	167	16.70	4.3	32.20	21	30.78
9	145	17.05	3.8	32.68	15	30.55
T_4 (Control)						
1	158	17.11	4.2	32.36	19	29.79
2	145	17.05	3.8	29.39	18	27.78
3	141	17.15	3.6	34.61	19	20.86
4	150	16.45	4.3	26.04	18	27.35
5	173	17.08	3.8	35.44	21	30.78
6	161	18.98	3.6	38.05	32	24.52
7	161	17.73	3.4	29.54	15	20.14
8	145	17.55	3.2	30.44	27	25.01
9	161	17.90	3.4	33.82	37	27.46

RAW SCORES OBTAINED DURING MAXIMAL WORK LOAD AT POST-TRAINING TEST

Subjects	HR	$\%O_2$	$\%CO_2$	$\dot{V}E$ (STPD)	LACTATE (mg%)	$\dot{V}O_2$ (ml/kg/min)
T_1(170-180)						
1	195	17.35	4.0	78.96	88	50.33
2	195	17.78	3.7	88.73	82	38.26
3	200	16.83	4.5	72.66	93	61.02
4	191	17.30	4.0	62.78	93	52.47
5	191	17.23	4.3	60.48	106	53.15
6	195	17.85	3.5	61.32	69	49.58
7	187	17.90	3.1	55.44	81	51.87
8	204	18.02	3.2	65.75	68	54.68
9	191	18.00	3.5	90.29	101	54.27
T_2(150-160)						
1	195	18.15	3.3	66.04	111	40.97
2	195	17.43	3.8	62.16	101	56.59
3	200	17.13	4.1	53.21	101	37.05
4	209	18.00	3.5	60.48	104	50.11
5	187	18.00	3.3	87.04	68	51.30
6	195	18.10	3.5	60.48	120	47.84
7	204	17.65	3.6	47.32	50	45.68
8	187	17.20	4.1	65.52	101	49.04
9	195	17.90	3.6	53.24	95	51.23
T_3(130-140)						
1	200	17.78	4.0	56.62	116	48.81
2	195	17.68	3.8	65.33	84	49.80

Subjects	HR	%O_2	%CO_2	$\dot{V}E$ (STPD)	LACTATE (mg%)	$\dot{V}O_2$ (ml/kg/min)
3	191	17.63	3.8	44.52	76	45.16
4	200	17.88	3.5	56.15	81	48.51
5	195	17.35	4.3	57.96	82	41.26
6	187	18.15	3.0	60.48	101	54.26
7	195	18.18	3.2	68.04	109	49.44
8	191	17.75	3.8	57.12	106	50.00
9	195	17.55	3.7	59.50	70	47.00
T_4 (Control)						
1	204	18.38	3.5	82.57	123	44.69
2	191	17.75	3.8	60.86	91	44.68
3	200	17.75	4.0	85.49	99	39.91
4	195	17.25	4.0	54.47	56	45.45
5	200	17.78	4.1	60.47	91	46.41
6	191	17.01	3.8	74.92	97	47.01
7	195	17.63	3.8	55.74	56	38.26
8	191	17.60	3.7	55.12	81	44.26
9	191	17.78	3.8	57.20	89	47.06